INDUCTION COILS:

HOW MADE AND HOW USED

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Dyer, pseud.

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PREFACE TO AMERICAN EDITION.

The rapidly extending use of the Induction Coil in the hands of investigators lends a renewed interest to the experiments to which this instrument may be applied in the lecture room.

The continued demand for a manual which has so long served as a guide to the application of *intensity* currents, has led to this reprint of the eighth English edition of the work entitled "Intensity Coils," by Dyer, under the present title.

January, 1881.

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INDUCTION COILS,

HOW MADE AND HOW USED.

1. Discovery of Current Electricity.—When the youthful pupil of Galvani accidentally brought the legs of a dead frog into an electric circuit, he witnessed the manifestation of an unknown force. Neither he who first saw the phenomena, nor they who afterwards repeated the experiments, had the remotest idea that the things they thought so curious were in fact only the germs of extraordinary discoveries. If these first manipulators in Current Electricity could not look *forward* to the stupendous result now achieved by its aid, it is almost equally difficult for us to look back upon their origin. We, whose statues and ornaments are produced by electric agency, whose bells are rung by its aid, who see rocks blasted and the obstructions in ports and rivers removed by its instrumentality, and whose thoughts can be conveyed, as it were, instantaneously, thousands of miles over rocky chains, desert wastes, and all but fathomless oceans, by the same won

drous power—even we can hardly realize that all this is to be traced to the accidental—perhaps mischievous—freak of a doctor's boy.

Without recurring to the physiological effects that once comprised all that was known of Galvanism, it will be necessary to advert to a few primary principles in order that the complex phenomena specially to be treated of may be properly understood.

2. Definition of Galvanism.—Galvanism may be defined as a manifestation of Electricity in a current form, produced by a chemical action.

Galvanism is an invisible agent; it is not to be apprehended by the touch; any or all of our senses may be brought to bear upon it, and yet it eludes our observation; it is only known to us by its effects. But it is a real force; it is one in nature with that mighty power which, in the form of lightning, rends the rocks, uproots the firmest trees, and has ever been regarded by man as a fitting emblem of Deity.

3. Manifestation of Galvanism.—Prepare a glass vessel, and partly fill the same with water made strongly sour by the addition of a little sulphuric acid. Into this plunge two plates of metal attached together by a copper wire, one metal plate being amalgamated zinc, and the other *platinized silver, Fig.* 1. Noticeable results fol-

low. The surface of the platinized silver becomes coated with minute bubbles which increase in size, and eventually are disengaged and rising through the liquid escape into the air. The whole of the liquid in the neighborhood of the platinized silver plate soon assumes a state of effervescence, while that surrounding the zinc is made free from disturbance. Distinct and marked though those effects are, yet they represent but a portion of the changes that are taking place. The zinc plate, by its superior affinity for oxygen (one of the elements of the water in the glass jar) decomposes the film of water immediately in contact with it, the result being the formation of an oxide of zinc over its surface. The other element of the water, hydrogen, eventually passes over to the platinized silver plate, and appears there in the form of the bubbles described. The oxide of zinc formed on the surface of the zinc plate is dissolved off by the action of the sulphuric acid in the water, forming sulphate of zinc, a fresh surface of zinc is exposed, another film of water is deprived of its oxygen, and another coating of oxide of zinc formed, and another equivalent of hydrogen is given up at the surface of the platinized silver plate. This will go on as long as there is any zinc left, or any capability in the water to dissolve the sulphate of zinc so formed.

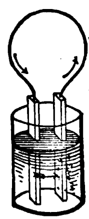

FIG. 1.

But the results do not stop here; not only has a new compound been formed at the expense of the zinc and the water; not only has one of the elements of the water been given up into the atmosphere in the form of a gas, but an entirely distinct, although invisible, force has been evolved. A current of galvanic electricity has been set up, starting from the zinc plate, passing through the fluid to the platinized silver plate. The electricity does not rest here, it proceeds up the silver plate to the attaching wire, and then through this wire back again to the zinc plate.

4. Evidences of the Existence of Galvanism.—But what proof, it may be asked, can be given that there is this invisible, intangible current flowing through the wire? How is its existence to be known? Another experiment will afford the evidence required. Prepare a glass vessel, partly filling the same with acidulated water (**3**)*, and before plunging in the zinc and silver plate, separate the wire that connects the plates together, as shown in *Fig.* 2. The effervescence before seen (**3**) as surrounding the silver plate will then be looked for in vain—all will be quiescent.

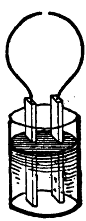

Fig. 2.

If now the ends of the two wires be brought

* These figures within brackets in the body of the text refer to the paragraphs bearing similar numbers.

into contact, the action observed in the former experiment (**3**) will immediately commence. Clearly, therefore, the effervescence seen in the fluid does not represent all that is taking place ; for it is evident that in some way or other a *connection* between the two plates is essential to the existence of any action at all.

Further, let the wires be again separated, and all action will cease. Bring the wires together again, but interpose between their ends a film of paper, ivory, gutta percha, or ebonite. By such an arrangement the plates are still united, but no action results. Separate the wires again, remove the intervening material, and replace it by a piece of brass, silver, or any other metal, and the action immediately recommences as at the first. Thus it is seen that not only must the plates be joined together, but they must be united by a material analogous to a metal, and not by one like paper, ivory, gutta percha, etc. It is evident something must flow through the connecting wire, and that unless the wire through its entire length be of a metallic kind, it is as though it were a severed or broken wire. It is also obvious that some substances possess the property of being conductors of what passes through the wire, and other substances do not possess that property.

5. Influence of the Connecting Wire on Magnet.—The foregoing will be carried a

step farther if it be found that the wire connecting the two plates possesses properties, while the action is going on, that do not belong to it under other circumstances.

Prepare the apparatus as used in the preceding experiment (**4**), first elongating the connecting wire, as shown at *Fig.* 3. The plates are to be put into the glass vessel before the acidulated water is poured in, and the connecting wire must be arranged so that it may come over an ordinary mariner's compass needle. The wire must coincide in direction with the needle, pointing north and south, and be about half an inch above it. No result whatever will follow; the wire, although attached to the plates, will have no influence on the compass needle any more than it would have had if it were detached from the plates.

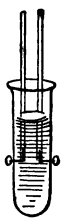

Fig. 3.

Let the acidulated water be now poured into the glass vessel, and the wire will be found to have acquired a marvellous power; the compass needle will be forced out of its position and stand oblique, as shown by the dotted lines, *Fig.* 3. This is not a transient movement; the needle will permanently remain in a position more or less oblique to the direction of the wire. If now the connecting wire be cut through, so as to separate it (**4**), all its powers will disappear, the compass needle will re-

turn to its original position, and all action will cease in the glass vessel.

This experiment clearly proves that, associated with the action going on in the glass vessel, there must be some power or influence traversing the connecting wire, and communicating to it properties that it did not previously possess. It also shows that such properties only exist while the action in the glass vessel is going on. This power or influence is called Galvanic or Current Electricity.

The connecting wire, under these circumstances, possesses other properties than those just described, but it will not be necessary to refer to them for the purposes of this paper.

6. Œrsted's Discovery.—The experiments just detailed appear to be very simple, but they have sufficed to open a wide field for scientific research. For a long time it had been doubted, and even denied, that an electrified wire (as a wire conveying an electric current is called) and a magnetized needle had any mutual relationship. It was not until the year 1819 that it was ascertained that such relationship did exist, and it is to Professor Œrsted, of Copenhagen, that the world is indebted for this discovery.

7. Galvanometers.—One of the early results of Œrsted's great discovery was the construction of instruments called Galvanomoters (or more

properly Galvanoscopes), for detecting the presence of electrical currents. A Galvanometer consists essentially of a magnetized needle suspended by a fibre or balance on a point with one or more strands of wire passing round it, the two ends of such wire being represented by two brass cups or binding screws, *Fig.* 4. When any arrangement is to be subjected to examination, it has to be attached to the binding screws of the Galvanometer, and if there be any electric current traversing it the needle will be acted on and deflected from its position (**5**). In arranging a Galvanometer for use, it must always be so placed that the needle, when at rest, may coincide in *direction* with the wire that surrounds it.

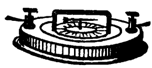

FIG. 4.

8. Action of Electrified Wires on other Wires.—An electrified wire not only possesses the power of forcing a magnetic needle out of its natural position, but it can affect also a continuous wire, which phenomena are well seen in the following experiments:

Place a plate of zinc and one of silver in an empty glass vessel (**5**). Fix a wire into the binding screws of the Galvanometer (**7**), and arrange the Galvanometer so that this wire shall be parallel to the wire connecting the two plates together, as shown in *Fig.* 5. These two wires must not touch each other, and should be about $\frac{1}{4}$ inch

apart. Two circuits are thus formed, one through the plates in the glass vessel and the wire that connects them together, and the other through the

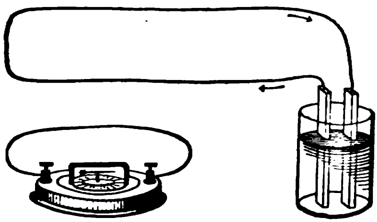

FIG. 5.

Galvanometer and the wire uniting the two binding screws. Let the acidulated water be now poured into the glass vessel, and the needle of the Galvanometer will be instantly forced out of its position, or, as it is usually termed, deflected (**7**). Thus we see that one electrified wire can originate a similar current in a wire near to but not in any way connected with it. The electrical current thus set up is called an Induced or Secondary Current, whereas the current in the wire connected with the plates in the glass vessel is called the Battery or Primary Current.

9. The Simple Battery.—The plates and glass jar and acidulated water used in the preceding experiments are designated a Simple Battery, by which name they will now be called.

10. Influence of an Electrified Wire on an Iron Bar.—Prepare the Simple Battery (**9**), and instead of using a straight wire to connect the plates together, twist it into the form of a helix, *Fig.* 6, and for this experiment the wire should be *insulated*, that is, covered with cotton, silk, or gutta percha. Place within this helix a small bar of iron, and then pour the acidulated water into the glass vessel. If the iron bar be now tested by applying iron filings or small tacks to its projecting ends, it will be found to have become magnetic. Remove the bar from the helix, and it will at once lose all its magnetic property. Replace it in the helix and it becomes magnetic; take the plates and helix and iron bar out of the solution in the glass vessel, and again all the magnetism of the bar disappears.

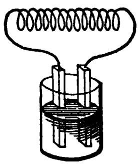

Fig. 6.

Thus it is evident that if a wire carrying a current of electricity be wound round an iron bar, temporary magnetism is communicated to the bar, which magnetism exists only as long as the iron bar is surrounded by the coils of wire and the electric current continues to flow.

11. Electro-Magnets.— This magnetic state is called Induced Magnetism, to distinguish it from the permanent magnetic condition of *steel* bars which we are familiar with in the form of

horseshoe-magnets. If, instead of using a feeble battery such as has been described, one of a more powerful description be employed, and if the iron bar be bent, as shown in *Fig.* 7, and several convolutions of wire be wound on it, an induced magnetic force can be obtained sufficient to sustain a weight of hundreds of pounds. Such a bar of iron, whether straight or bent, is termed an electro-magnet.

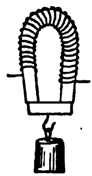

FIG. 7.

12. Action of a Steel Magnet of a Helix of Wire.—Attach a wire helix (**10**) to the Galvanometer, as shown, *Fig.* 8. No effect will be produced on the Galvanometer by the helix, but if a permanent steel magnet, **A**, be passed into it, the Galvanometer will be at once influenced, and the needle deflected. Thus it is seen that an electrical current can be excited in a wire by the action of a permanent magnet, as it was seen (**10**) that magnetism can be excited in an iron bar by the influence of an electrified wire.

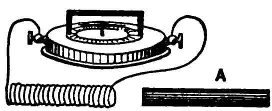

FIG. 8.

13. Increased Effects resulting from Increased Current Action.—All the effects produced by the Simple Battery described in the preceding experiments may be increased by employing a more powerful battery, but the difference

will be in extent only, the phenomena themselves remaining the same.

Although, in performing these experiments, it does not at first sight seem that much has been done, yet it is from the principles thus demonstrated that the wonderful science of Telegraphy has proceeded. However complicated and surprising the present condition of that part of science is, Telegraphy is but the application of the facts shown in the experiments just detailed to some of the requirements of daily life.

14. Current, or Dynamic Electricity.—The electricity evolved by a galvanic battery is designated Current or Dynamic Electricity (**5**), and requires for its conveyance a complete circuit of some conducting substance or substances from the plate emitting the current back to the same plate again.

15. Static Electricity.—There is another condition of electricity called Static Electricity that should be adverted to, as both states are manifested by the Intensity Coil. The Static condition of electricity differs from the Current in that it may be regarded as a state of quiescent accumulation. It is associated with some *surface*, which is then said to be *charged*, and

Fig. 9.

such surface will emit sparks whenever any conductor is presented to it. A familiar experiment will illustrate this. Take a stick of sealing-wax, and rub one end briskly with a piece of fur or flannel, *Fig.* 9. When this has been done, the wax will become electrically excited, and if the knuckle be passed over the surface a series of small sparks will be seen, accompanied with a crackling noise. This is electricity in the Static condition.

GALVANIC BATTERIES.

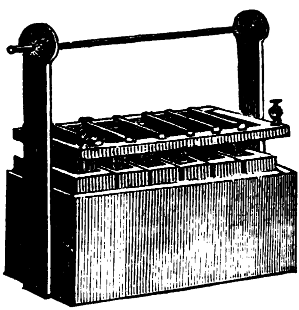

Fig. 10.

16. Galvanic Batteries.—It will be proper now to give some explanation of the various kinds of Galvanic Batteries that are generally employed. This will prevent any further reference

to specific forms of battery, when the experiments with the Intensity Coil are described. The term "the Battery" will then be used, and that phrase will be taken to express the particular kind, as well as the number of cells that may have been selected.

17. Elements of a Galvanic Battery.—To constitute a Galvanic Battery it is necessary (**3**) to have two dissimilar substances or surfaces, both being conductors of electricity, and they must be placed in a fluid that will act more energetically on one than on the other. The substance or surface *less* acted upon is called the *Negative element*, and that *more* acted upon the *Positive element* of the battery. The substances or surfaces may be flat or circular; they may be near together or more widely asunder; they may be both of them metallic, or only one of them a metal; such variations only affect the *force* of the electric current evolved. The materials used as the elements of Galvanic batteries are usually such as these: Copper and Zinc, Silver and Zinc, Platinum and Zinc, Carbon and Zinc, Cast Iron and Zinc; and for the exciting fluids, Sulphuric and Nitric Acids, Bichromate of Potassa, and Sulphate of Copper. Many other combinations can be employed for evolving electric currents, but results so obtained are more interesting in a scientific than *in a practical* point of view. Therefore the Cruik

shank's, Daniel's, Smee's, Grove's, Callan's, Bunsen's, and the Bichromate batteries, which are those that require the materials mentioned, will alone be described.

Only one of the elements of the battery is acted upon by the exciting fluid, and dissolved (or worn away, as the usual phrase is). This is the *positive* element, while the other, which is not acted upon or worn away, is the *negative* element.

18. Poles of a Galvanic Battery.—Much confusion exists in the minds of many persons with reference to the terms the Positive and Negative *elements* of a battery and the Positive and Negative *poles* of a battery. This is readily dissipated by observing that the term ELEMENT is applied to that part of the plate of a battery that is *within* the exciting fluid, such being the active part of the plate, and the term POLE to that part of the plate that is *without* the fluid and which becomes the conductor only. The term POSITIVE is intended to signify *that* from whence the current proceeds, while the NEGATIVE signifies *that* which the current enters. By a reference to the accompanying illustration, it will be seen that the same plate of a battery is the *positive* element and the *negative* pole. By following the course of the arrows, *Fig. 11*, it will be found that the current flows from

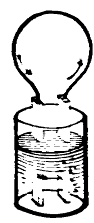

FIG. 11.

one plate through the fluid, and up the other plate. It then passes from the end of that plate through the wire that connects the two together to the top of the plate from whence it originally started. Thus it is that *each* plate of a battery has opposite terms applied to it, one part being called Positive and the other part Negative.

19. Electrodes.—Dr. Faraday disuses the word *pole* altogether, and calls the ends of the elements that are outside the exciting fluid ELECTRODES, the paths or ways of the electricity; and to express the *emitting* or Positive Electrodes, he prefixes the syllable AN, and to express the *receiving* or Negative Electrode, the syllable CATH. So that, in the language of that distinguished man, the upper end of the Negative element of the battery (usually called the Positive *pole*) is the emitting or An-electrode, and the upper end of the Positive element (usually called the Negative *pole*), is the receiving or Cath-electrode. For convenience of pronunciation, these two words are shortened to anode and cathode; and in deference to so distinguished an authority, these terms will be used throughout this book, instead of the words positive pole and negative pole.

20. Compound Batteries.—In the foregoing remarks, a simple or single cell battery only has been described. But the principles detailed belong equally to any multiple of the singl

cell, forming what is then called a Compound Battery.—*Fig.* 10, *Fig.* 62.

21. Quantity Arrangement of a Battery.—In uniting single cell batteries to form a compound battery, the anode of each single cell battery may be attached to one metallic bar or wire, and the cathode of each single cell to another similar bar or wire. This is called the quantity method of arrangement, and the effects obtained from such a compound battery will be similar to those that would be produced by a single cell battery, the plates of which were equal in surface to the sum of all the plates in the compound battery. Such a method of connection converts, in fact, a *number* of small batteries into *one* large one.

22. Intensity Arrangement of Battery.—If it be desired to give to the current of electricity evolved from any single cell battery a greater power of overcoming obstacles, then other batteries must be united with it in such a manner that the current from the one battery will circulate *through* all the batteries that are added to it. This is called the intensity arrangement, and it requires that the anode of one battery be united to the cathode of the next, and so on through the entire series employed.

23. Necessity for Uniformity of Size in Batteries.—In uniting single batteries together to form an intensity arrangement,

care should be taken to use batteries whose negative elements are of *equal* size. If this be not attended to, the power of the series will be reduced to what it would be were all the batteries the size of the *smallest* one. The absolute power of any galvanic battery, all other things the same, depends upon the area of the surface of the *negative* element.

24. Electrodes of Compound Batteries.—When a compound battery is arranged as a quantity battery (**21**), any part of the bar or wire to which the anodes of the single batteries are united will form the anode of the compound battery; and any part of the bar or wire to which the cathodes of the single batteries are attached will be its cathode. When single batteries are arranged for an Intensity Battery (**22**), the *unconnected* cathode of the first battery will be the cathode of the series, and the *unconnected* anode of the last battery will be the anode of the series. To attach a Galvanic Battery, whether a simple or compound form, to any piece of apparatus, it is only necessary to carry wires from the two electrodes to the apparatus that is to be employed.

25. Continuity of Circuit.—The effects producible by a Galvanic Battery are manifested in the passage of the current from one electrode to the other (**4**); and therefore, in ar-

ing a Galvanic Battery and apparatus, an uninterrupted conductor, of some kind or other, must be provided between the two electrodes.

BATTERIES, HOW CONSTRUCTED.

26. Cruikshank's Battery.—This battery is only used as a Compond Battery (**20**). It consists of plates of zinc and copper united together in pairs, and fitted into grooves in the sides of a wooden trough. A suitable space is left between the pairs of plates, and this space forms the cell for receiving the exciting fluid. Cruikshank's battery is excited with a dilute solution of sulphuric acid, with slight addition of nitric acid, but it is not a very convenient form for experimental purposes. It is used for telegraphic purposes, and also for medical galvanism.

27. Daniel's Battery.—This admirable battery consists of a copper cylinder, in which is placed a cylinder of porous earthenware, and in this a zinc rod, *Fig.* 12, the zinc being the *positive*, and the copper the *negative* element. Two exciting solutions are required for this battery; one a saturated solution of sulphate of copper, and

Fig. 12.

the other a solution of sulphuric acid (commercial oil of vitriol) in the proportion of seven parts of water by measure to one part of sulphuric acid. The solution of sulphate of copper is placed in the copper cylinder, and the diluted sulphuric acid in the porous cylinder. The porous cylinder keeps the two solutions separate, and at the same time allows the electric current to pass through its sides. A binding screw attached to the zinc rod, and one attached to the copper cylinder, form the cathode and anode (**19**). It is not necessary to have any containing vessel for this battery; the copper cylinder being closed at the bottom performs that office. This battery is very effective in use, remarkably constant, and gives a current of considerable intensity.

28. Smee's Battery.—This form of battery has perhaps been more extensively used than any other galvanic arrangement. It consists of a plate of platinized silver for the *negative* element with two plates of zinc for the *positive* element, *Fig.* 13. The platinized silver plate is usually attached to a wooden bar, and the zinc plates, being placed one on each side of the same, are kept in the required position by a metal cramp passing over the

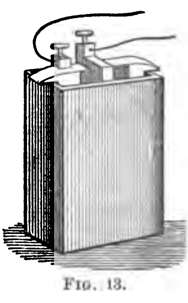

FIG. 13.

of the bar. A binding screw, passed through the wooden bar and attached to the silver plate, forms the anode, and a similar binding screw, on the cramp that holds the zincs to the bar, is the cathode. An earthenware or other suitable containing vessel is required for this battery, and it is excited by a solution of sulphuric acid (commercial oil of vitriol) in the proportion of 7 parts of water by measure to 1 part of sulphuric acid. This battery is admirably adapted for electro-depositions and also for general galvanic experiments; but it is not the most suitable kind for producing electric light, nor for the intensity coil. It is easily managed, is tolerably constant, and requires only one exciting fluid; and therefore porous cells are dispensed with.

29. Grove's Battery.—The elements of this battery are platinum for the *negative* and zinc for the *positive*. This battery also requires a containing vessel to hold the entire arrangement, and an inner cell to hold the platinum plate only. This inner cell, like that in Daniel's battery (**27**), must be of a porous earthenware, which will admit the passage of the galvanic current through its sides, but will not allow the exciting fluids to mingle. When the zinc plate is placed in the containing jar, the porous cell is to be put between the upright portions of the zinc, and the platinum plate is then put into the porous

cell, *Fig.* 14. The zinc plate is usually made out of a long strip bent up in the form of the letter U,

FIG. 14.

by which means the zinc is brought opposite to each side of the platinum plate.

But it is more advantageous, instead of bending a long slip of zinc, to employ three shorter pieces. One piece to be put at the bottom of the containing jar, and two other pieces resting on this to form the two vertical sides. This is less expensive to make and more economical in use. A binding screw attached to the zinc plate, and one to the platinum, form the two electrodes.

Two different exciting fluids are required for this battery, one for the platinum cell and the other for the zinc. That for the platinum is, nitric acid (commercial aquafortis) 3 parts, and sulphuric acid 1 part; and that for the zinc, sulphuric acid (commercial oil of vitriol), 1 part by measure added to 7 parts of water. This battery is convenient in use, and is admirably adapted for general galvanic experiments, especially so for the intensity coil, but it is not generally suitable for manufacturing purposes.

30. Bunsen's Carbon Battery.—The elements of this battery are zinc for the *positive*, and carbon for the *negative* element. A porous

cell and containing jar, and two exciting fluids, are required for this battery. The general arrangement of the Bunsen's Battery, and the nature of the exciting fluids are precisely similar to those of Grove's Battery (**29**). The carbon usually employed for Bunsen's Battery is obtained from the deposited carbon that is found in the retort at the gas works.

31. Callan's or Maynooth Battery.—A cast-iron vessel is used in this battery as the containing cell, and this forms the *negative* element. A porous cell is placed within the iron one, and the zinc plate which forms the *positive* element is put into it, *Fig.* 15. Nitric acid is used in the iron cell as the exciting fluid, and sulphuric acid (commercial oil of vitriol), 1 part by measure added to 7 parts of water, is used in the porous cell. Many experimenters admire this battery; it is moderately cheap to construct, exposes a large negative surface, and evolves a powerful current; but its cost in use is considerable, owing to the large quantity of nitric acid required.

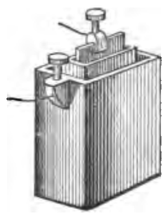

Fig. 15.

32. Bichromate Battery.—This consists of a plate of gas carbon for the *negative* element, and a plate of zinc for the *positive.* These plates are attached to a bar, and suspended in the

containing jar; no porous cell is required and one exciting fluid only is used. The exciting fluid is thus made: Dissolve powdered bichromate of potassa in hot water, the proportion being about 2 ounces of bichromate to 1 pint of water. When cold, add sulphuric acid (commercial oil of vitriol) in the proportion of 1 part of acid to 12 parts of bichromate solution. The addition of the acid will cause the evolution of a considerable degree of heat, and when the solution is again cold it is fit for use. This battery is convenient in use, does not emit any fumes, is very energetic, and will maintain its power about three hours.

A very convenient preparation has recently been introduced for forming the solution for the Bichromate Battery. It is known as "Allen's Crystals for the Bichromate Battery," and it only requires to be dissolved in the proportion of 1 ounce of the crystals to 4 ounces of water, and the solution is ready for use, without any further addition.

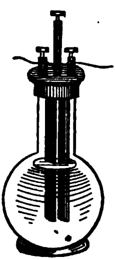

Fig. 16.

A useful form of the Bichromate Battery is that shown in *Fig.* 16, which has a glass bottle for the containing cell, and the zinc plate is in the centre, with a carbon plate on each side. The zinc is attached to a rod that passes up through the cap of the bottle, so that it

can be drawn up or down. In charging the bottle-shaped cell with the exciting fluid, the vessel should not be filled higher than the body, so as to leave the neck empty. The zinc plate is made somewhat shorter than the neck of the bottle, and when the battery is not required for use the zinc can be drawn out of the solution in the body into the empty neck of the bottle, and then all action at once ceases. The solution can be left in the cell, and will keep good any length of time, and the battery can be put into action whenever required.

All the batteries described (**27** to **32**) can be used either as single or compound batteries, and can, if arranged as compound batteries, be connected either for quantity or intensity effects.

33. Amalgamation of Zinc Plates.— The zinc plates used for the Smee's, Grove's, Callan's and Bunsen's Batteries, should be amalgamated when the battery is first made, and they will require to be re-amalgamated from time to time. This is very readily effected by laying the zinc plate in dilute sulphuric acid of the strength used for the exciting solution, and allowing the plate to remain for some few minutes. It should then be taken out, and, while wet, have a globule or two of mercury placed on it, and rubbed over its faces and edges, so that it may present a uniform silvered appearance. This amalgamating is necessary in

order to prevent what is technically called *local action*, and its necessity may be thus exemplified. If a piece of *unamalgamated* zinc be put into dilute sulphuric acid, the surface will be immediately covered with minute bubbles of hydrogen gas, and the acid solution will soon be in a state of effervescence, accompanied with a hissing sound. This will go on until the zinc is entirely dissolved, or the solution completely saturated with sulphate of zinc. But if the zinc plate be amalgamated, no action of this kind will take place; the smoothness of the surface communicated by the mercury appears to cause the hydrogen first evolved to *adhere* to the plate, which is thus protected from any further action. This immunity only exists while the zinc plate is detached from the other part of the battery, or the circuit between the anode and the cathode is severed. When the zinc plate is in its place, and the circuit completed, the mercury affords no protection, as the hydrogen then is evolved at the negative element (**3**). When the zinc plates of a battery, after being washed, look black in parts, it is needful to re-amalgamate them previous to using them again.

34. Elements of a Battery to be kept apart.—It will be obvious, from the foregoing remarks, that the positive and negative elements of a battery must not touch each other *within* the exciting fluid. They should be about

$\frac{3}{8}$ to $\frac{1}{2}$ inch apart, and the batteries that are used without porous cells will require to be examined from time to time, in order to see that these conditions have not become deranged.

INDUCED ELECTRICITY.

35. Induced Currents.—In a previous experiment (**8**) it was shown that an electrified wire is capable of exciting an electrical current in a wire that is contiguous to but not connected with it. This kind of current is called an Induced Current. The Induced Current differs strikingly from the Battery Current, inasmuch as the Battery Current is continuous as long as the circuit is complete, whereas the Induced Current is but momentary, and requires a disruption of the Battery Circuit to re-excite it. The experiments (**36** to **43**) will serve to illustrate the phenomena of Induced Currents, and will render more obvious the descriptions that will be given.

36. Induced Current on Completing Circuit.—Fix two wooden pillars, A, B, into the top of a wooden base, *Fig.* 17. The height of these pillars, or their distance apart, is not of material moment. If the pillars be made

6 inches high, and be about 12 inches apart, such a proportion will be convenient. The top of each pillar should have two binding screws in it, so that

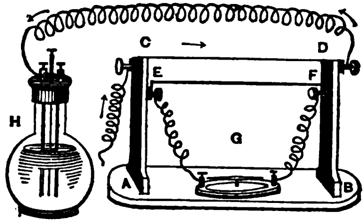

Fig. 17.

the bent wires C D and E F may be fitted in one below the other, and about ¼ inch apart. The Galvanometer, G, is to be connected with the two binding screws carrying the lower wire, E F, so as to form a continuous and closed circuit. The cathode of the battery, H, is now to be connected with the binding screw D, forming one of the ends of the wire C D. It will be seen that the battery circuit is not yet completed, for the wire from the binding screw C is not connected with the anode of the battery; therefore all is quiescent. If the battery circuit be completed by touching the anode of the battery with the wire from the binding screw C, the needle of the Galvanometer will be immediately deflected into an oblique position. This deflection, as observed be-

fore (**8**), is caused by the induced current of electricity that is set up in the *galvanometer* circuit by the action of the current that circulates through the *battery* circuit as soon as this latter is completed.

37. Induced Current on Rupture of Circuit.—Let this be pursued further. Instead of simply *touching* the anode with the wire C, let the wire be *fixed* to the anode by means of its binding screw. A similar deflection will take place, but it will be seen that it exists only for an instant; the needle will soon return to its normal position, although the contact of the wire with the battery is still preserved. This shows that an induced current differs from the battery current in that it is but transient (**35**), and does not flow continuously. Separate the wire C from the anode of the battery, and again the needle will be deflected; but it will be observed that the deflection is now in the *opposite* direction to the former deflection. This also only lasts for a moment, and the needle will then return again to its original position.

38. Necessity for Rupture of Battery Circuit.—These experiments will enable the phenomena of induced currents to be better understood, for they show that the influence of an electrified wire upon a contiguous wire brings *about an alteration* in the electrical state of such

wire; and this, in the present case, is shown by the deflection of the needle of the galvanometer. It is also seen that this electrical manifestation exists only *while* the alteration in the electrical condition of the wire is being brought about, for as soon as the alteration is effected it ceases. But more than this is shown, as it is manifest that the battery current has the power, not only of *producing* this alteration in the electrical state of the contiguous wire, but also of *maintaining* that altered condition, for the needle soon returned to its normal position, although the battery current continued to flow. Even this is not all, for when the battery circuit was interrupted by separating the wire from the anode of the battery, then the force that had been operating ceased, the wire in the galvanometer circuit returned to its normal condition; but in doing this another current was set up, manifested by the second deflection of the needle, a current, be it observed, differing in some respects from the first, inasmuch as the deflection of the needle was in the opposite direction.

39. Rapid Rupture of Battery Circuit.—Let the mode of performing the experiment (**36**) be varied by attaching the wire from the file J, *Fig.* 18, to the anode of the battery. The file under these circumstances becomes the electrode; and if the end of the wire from C be brought into contact with the file, the needle will

be deflected as before. Make contact by again touching the file with the end of the wire from C, and draw it along the surface of the file. This process will give a succession of contact-making and contact-breaking; for every time the wire

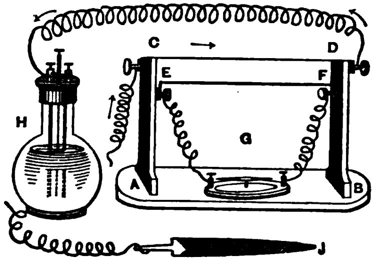

Fig. 18.

passes off one tooth of the file, contact will be broken, and each time it again touches the next tooth contact will be renewed. Under these circumstances the needle of the galvanometer will be kept in a state of oscillation. The rapidity of the operation of making and breaking contact enables the induced electricity which only exists for a moment to approximate to the character of a continuous current.

40. Induction in the Battery Circuit.—There is another condition of Induction that will require to be noticed in order to enable all the *phenomena* of the Intensity Coil to be un-

derstood. In the preceding experiment the action of an electrified wire upon an independent wire was noticed; it will now be seen, that under certain circumstances, an electrified wire acts upon *itself*. Prepare a battery (say that shown at *Fig.* 16), and attach one end of an insulated wire, about 18 inches long, to the cathode. The other end of the wire is to be brought into contact with the anode and then separated, when a *minute* spark will be seen at the point of rupture, *Fig.* 19.

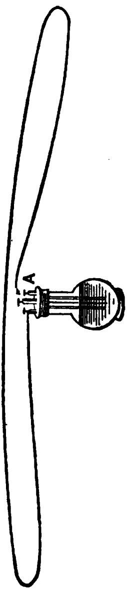

Fig. 19.

41. Induction in Scalariform Battery Wire.—Remove the wire from the battery, and bend it into a scalariform or ladder-like shape. Repeat the former experiment with the wire thus arranged, and the spark will be perceptibly larger and brighter.

42. Induction in Spiral Battery Wire.—Change now the form of the wire by winding it into a spiral or helix, C, *Fig.* 20. On repeating this experiment with the wire in this shape, the spark is still further increased.

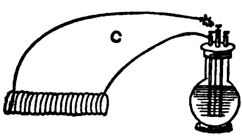

Fig. 20.

43. Magnetic Induction in Battery Circuit.—Repeat the former experiment (**42**), first inserting the rod, D, *Fig.* 21, into the centre of the helix, C, and when contact with the battery

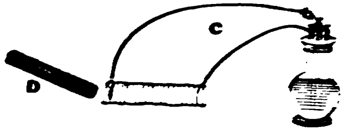

Fig. 21.

is broken under these altered circumstances, the force and brilliancy of the spark will be further intensified.

The explanation is this: In the first experiment (**40**) the spark was produced by the combustion of the conducting wire by the unassisted force of the battery current. In the second and third experiments (**41** to **42**), the *increase* in the spark was due to increased combustion of the conducting wire arising from the inductive action of one fold of the wire upon that contiguous to it. In the fourth experiment (**43**), the iron rod in the centre of the helix was rendered magnetic by the flow of the battery current round it, and this magnetized rod in its turn acted on the helix, and thus still further increased the force of the current.

If a galvanometer (**7**) be made a part of the circuit in performing these experiments (**40** to **43**), the effects described will be seen in the increasing length of the arc through which the needle will be deflected. It must be noticed that

these increased effects are manifested at the moment of breaking battery contact, and, like the former results (**36**), they are but transient, and only approximate to continuity by a rapid process of contact breaking.

44. Electro-Chemical Effects of Current Electricity.—Prepare a piece of white blotting paper by immersing it in a solution of starch, and then drying it. Moisten the paper thus prepared with a solution of iodide of potassium, and lay it on a glass or ebonite plate. Arrange the battery so that the wires (which in this case must be platinum) from the electrodes may come down upon the moistened paper, *Fig.* 22.

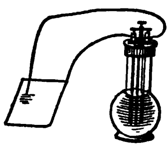

Fig. 22.

Let the ends of the wire be about $\frac{1}{2}$ an inch apart, and in the course of a few seconds there will be a violet spot under the end of the wire from the anode of the battery. This color results from the decomposition of the iodide of potassium by the galvanic current and the union of the iodine thus liberated with the starch that the paper was prepared with, forming iodide of starch, which is of a deep violet color.

HOW A COIL IS MADE.

45. The Primary Coil.—From experiments such as the preceding, it is obvious that by arranging the wire used for uniting the two electrodes of a galvanic battery into the form of a helix, certain properties of the battery are greatly increased. When a long length of wire is used, it is best to wind it in two or more layers, one over the other. Such a helix is designated a Coil, and, because it is employed for conveying the battery current, it is called a Primary Coil. Whenever the word Primary is used with reference to galvanic arrangements or experiments, it is intended to signify some relation to a battery circuit.

46. Construction of an Ordinary Primary Coil.—Prepare a paper tube, about 4 inches long and $\frac{3}{4}$ in. diameter, and wind on this tube two or three strands or layers of wire, one over the other. The wire should be copper, covered with cotton, and of the size of ordinary bell wire. A binding screw should be attached to each end of the wire, as shown in *Fig.* 23, by which means it can be conveniently united to a battery. This is a Primary Coil, and by its aid the results observed in **42, 43,** can be obtained in a more marked and palpable manner. When the paper

tube upon which the wire is wound is filled up with an iron bar, greatly increased effects are manifested, and if, instead of a solid iron bar, a bundle of iron wire, A, *Fig.* 23, be employed for this purpose, the improvement is most striking.

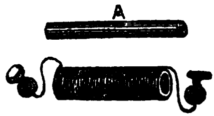

Fig. 23.

47. Construction of an Ordinary Secondary Coil.—Prepare a second paper tube of similar length to that in the centre of the Primary Coil just described, but large enough in diameter to fit over it. Fit two discs of wood on the ends of this tube, and then wind on five or six strands of cotton-covered wire about the size of stout packthread, and attach binding screws to the beginning and end of such wire. This, when placed over the Primary Coil, is termed a Secondary Coil, *Fig.* 24. It is contiguous to the Primary Coil, but has no connection with it.

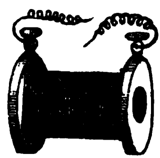

Fig. 24.

48. Sparks from Secondary Coil.—Place two thin wires in the binding screws of the Secondary Coil, and bring their ends near together, so that they all but touch, and place the Primary Coil, with its core of iron wires, within the Secondary Coil. Attach the Primary Coil to a battery, and break contact rapidly by means of a file (**39**), when a series of minute sparks will be

seen between the ends of the wires from the Secondary Coil (**47**). If the fingers be wetted and brought into contact with the two binding screws on the Secondary Coil, or with metal cylinders attached to them, a distinct shock will be felt when the contact between the Primary Coil and the battery is made or broken. It is thus that the coils of the electro-magnetic machines are constructed that have been made and sold by thousands, both for medical and experimental purposes. But such machines are not Intensity Coils, for their mode of construction involves the loss of all but a mere fragment of the electrical current excited in the wires of which they are composed.

49. Contact Breakers.—As the induced currents (**36, 38**) are only manifested when contact between the Primary Coil and the battery is made and broken, it will not be out of place to describe here the means by which this rupture is usually effected. The contrivance for this purpose is called a Contact Breaker, and it will only be necessary to describe two kinds, as they may be taken as types of those in ordinary use.

50. The Mercury Contact Breaker.—In *Fig.* 25 is represented an apparatus devised by Dr. Ritchie, as a mode of obtaining rotary motion by the temporary magnetization of an iron bar; and this has been extensively employed as a Contact Breaker. It consists of a circular disc of

wood placed between the poles of a horseshoe magnet, having a deep channel turned in it, so as to form a cup. This cup is divided into two parts or semi-cups by a wooden bridge, the ends of which come opposite to the poles of the magnet. A brass pillar rises up from the centre of the bridge, supporting on its top an iron bar wound round with insulated wire, the two ends of which come down into the cup, and are of such a length, that when the iron bar is rotated, they will just pass over the bridge without touching it. This bar, or Electro-magnet (**11**), as it really is, has a pointed pin projecting from its underside, which fits into the brass pillar, and this arrangement allows the bar to rotate with very little impediment from friction. The two semi-cups are to be filled with mercury, which will stand up above the top of the bridge, the bridge thus causing a sort of trough between them.

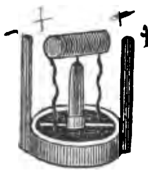

FIG. 25.

The wires from the electrodes of a battery are to be put into the mercury in the semi-cups (one into each), and the rotating bar moved round so that it may stand *across* instead of in the line of the bridge. As soon as this is done the wires from the iron bar will touch the mercury, and the battery current will then circulate round the bar and convert it into an electro-magnet (**11**). The

north and south poles of the horseshoe magnet will attract dissimilar poles, produced in the iron bar by the action of the battery current in the iron bar, and draw them round until they are opposite to the two poles of the horseshoe magnet. This operation will also carry the wires out of the mercury, and communication with the battery will be interrupted, and consequently the electro-magnet will lose all its properties.

At first sight it would appear that the electro-magnet would now come to a state of rest, but this is not the case: the impetus it acquired by its partial rotation will carry it a little beyond the line of the bridge, and this will bring the points of the wires again into the mercury in the semi-cups. But it will be noticed that the wires do not come into the same semi-cups as before, and that the battery current therefore flows through the wire on the iron bar in the opposite direction; consequently the polarity now acquired by the bar is opposite to that which it had before. The end of the electro-magnetized bar that is *now* north is thus near to the north pole of the horseshoe magnet, and these two mutually repel each other, and by this force the rotating bar is driven to a posi tion at right angles to the bridge, and where its north can be attracted by the south of the horseshoe magnet. This attractive force carries the bar through another quarter of the circle, and it is

brought again with its wires over the bridge. But the wires coming again into the opposite semi-cups, opposite polarity is induced, again it is driven through a quarter circle, attracted through another quarter of the circle until it is once more over the bridge.

In this way, by this alternate magnetization and demagnetization, an attractive and repulsive action is obtained, by means of which a rapid rotation is produced, and contact made and broken twice in each revolution.

This, though a convenient Contact Breaker for some purposes, is not suitable for use when large batteries or coils are employed. Every time the wires leave the mercury a vivid spark occurs, and the surface of the mercury soon becomes covered with a coating of oxide of mercury. This oxide being a non-conductor prevents the battery current from flowing into the wire, and so interrupts the action. These inconveniences are remedied by the form of Contact Breaker now to be described, and which is usually called the Vibrating Contact Breaker.

51. Vibrating Contact Breaker.—By a reference to the illustration, *Fig.* 26, the general form of this Contact Breaker will be seen. It consists of a base-board having an outer brass pillar, a centre brass pillar, and an electro-magnet **(11)**. The electro-magnet is fixed to the board

with its poles upwards, and the ends of the wire that is wound round it are thus disposed of. One end is left open, so that the battery may be connected with it, and the other end passes under the board to the base of the centre pillar. The outer pillar, at its upper part, holds the end of a metal spring

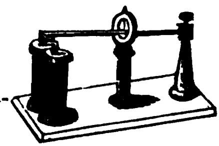
FIG. 26.

which passes through the ring of the centre pillar to the poles of the electro-magnet. Here the end of the spring is armed with a plate or clapper of iron, which should stand when the spring is at rest about 1-10th of an inch above the poles of the electro-magnet. A screw passes through the ring at the top of the centre pillar, and comes just in contact with the spring. The spring at this point, as well as the end of the screw, must be of platinum.

When one electrode of a battery is attached to the open end of the wire of the electro-magnet and the other electrode to the outer brass pillar, the circuit is complete. If the anode of the battery (**19**) be connected with the electro-magnet, the current will enter there, circulate round it, communicate magnetic properties to it, and pass under the board to the centre pillar. It will rise up here to the ring and descend through the screw to the spring, and from thence by the outer pillar to the cathode of the battery.

The electro-magnet will now attract the iron clapper at the end of the spring down to itself, and by this means a separation takes place between the end of the screw and the spring, and the battery circuit is interrupted. The electro-magnet then loses all its attractive power; it can no longer hold the clapper down, and the spring thus liberated rises to the position it formerly occupied, and again comes into contact with the end of the screw that passes through the ring. As soon as this takes place the current again flows, the electro-magnet exercises attractive influence on the clapper, and draws it down. This once more breaks contact, again the spring resumes its position, and thus a rapid vibration is kept up; every oscillation of the spring being associated with making and breaking contact with the battery.

When this contact breaker is applied to Intensity Coils, it is usual to employ the iron bundle forming the core of the coil (**46**) as the electro-magnet, and to place the vibrating spring vertical instead of horizontal.

HOW AN INTENSITY COIL IS MADE.

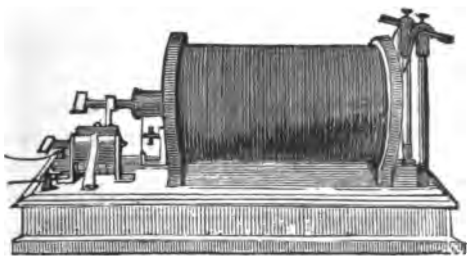

Fig. 27.

52. Intensity Coils.—It is to M. Ruhmkoff, of Paris, that the scientific world is indebted for a knowledge of the means by which the entire results of the combined action of battery, wires, and iron core can be obtained. M. Ruhmkoff may, therefore, be properly regarded as the inventor of the Intensity or Induction Coil. As it is proposed to give in detail instructions for making as well as using these coils, it will not be necessary to do more than advert thus to the inventor, as the elements of the invention itself will be found in the directions that are to follow.

The parts of an Intensity Coil are these—the Reel, the Primary Coil, the Secondary Coil, the

Iron Bundle or core, the Contact Breaker, the Condenser, the Pedestal or base, and the Commutator. The dimensions about to be given are not intended to be taken as expressing the absolute relation that must exist between the various parts of an Intensity Coil. They may be considerably varied without impairing the efficiency of the apparatus.

53. The Reel.—The Reel consists of a hollow cylinder or tube, with a square or circular plate firmly fixed on each end of the same. The cylinder should be formed of paper, and the plates or reel ends, as they may be called, should be of gutta percha or ebonite.

The reel ends should be flat, and not less than $\frac{3}{8}$ in. thick, and if circular a facet should be made on the edge of each, so that when the reel is complete it may stand steadily on the pedestal. The hole through the centre of the reel ends should be turned perfectly true, so as to fit the outside of the cylinder, and a shoulder should be left on the outer face sufficient to prevent the paper cylinder from being pushed through the ends when it is being fastened on. The reel ends may be $4\frac{1}{2}$ inches diameter if circular, or 4 inches by 4 inches if square. They can be fastened to the paper cylinder by Thompson's Liverpool glue or cement.

The cylinder should be formed of cartridge

paper cut into a long strip, and when gummed or pasted on one side, wound round a rod $\frac{7}{8}$ inch diameter. When properly done a firm tube, 7 inches long, 1 inch diameter, and about 1-16th of an inch thick, is obtained. This is to be allowed to dry thoroughly, and the ends cut perfectly at right angles to the axis. The discs or ends must be firmly fastened to the cylinder, and in order to effect this the holes through the discs should be slightly tapered, the larger dimensions being towards the shoulder. Before fixing the paper cylinder a slightly conical plug should be provided, fitting the inside of the cylinder. When the parts are ready and carefully coated with the glue, they are to be put together, and the conical plug gradually pressed into the end of the cylinder, which will expand it a little and force it into close contact with the sides of the hole in the disc, and it is to remain in this position until the glue is thoroughly set, when the plug can be removed. The Reel should be provided with a hollow groove in the edges of the discs, if they be circular, in order to receive the pieces of catgut cord that are to fasten it to the base; if they be square they can be fastened by screws. Two holes are to be drilled through one of the ends of the reel, in order to allow the primary wire to be passed through. These holes should be about $\frac{1}{8}$ in. diameter, and they should be somewhat oblique in their direc-

tion, so that the wire where passed through the reel end may not be at right angles with the axis of the reel.

54. The Primary Coil.—The Primary Coil consists of copper wire covered with cotton, and of a size known as No. 16. averaging about 18 yards to the lb. One end of the wire is to be passed from the inside through one of the holes in the reel end, so as to project six or eight inches, and the wire is then to be carefully wound over the cylinder up to the other end, and then back again, so as to form two layers of wire over the other. When this is completed, the remaining end of the wire is to be passed through the second hole in the reel end. Such a quantity of wire will weigh about one pound. Before putting on the wire it is necessary to fit a wooden or metal rod inside the paper cylinder of the reel. If this be not done, the cylinder is likely to be damaged by the force required to wind the wire round it.

When the Primary Wire is laid on, it should be varnished with two or three successive coats of varnish composed of shellac dissolved in spirits of wine. Care should be taken that one coat be thoroughly dry before a second is put on. The varnish for the first coat should be thin, so that it may be readily absorbed by the covering of the wire and conveyed to the underneath layer. When the varnish is dry and hard, the primary wire is to be

carefully covered with a strip of cartridge paper passed twice or three times over the wire, and fastened by gum-water or glue. This paper must be cut exactly to the width between the inside faces of the ends of the reel. It must be drawn tightly when put on, but not so tightly as to show on its surface the interstices between the rows of wire. This paper covering, when dry, is to be carefully varnished, and must present a smooth cylindrical surface, having no interspace between it and the inside face of the reel ends.

Shellac varnish, laid on as above described, forms a good insulator, but it is not quite so effective a mixture as the ordinary black rosin of commerce and beeswax. This preparation is rather more difficult to apply, but it is greatly superior to the varnish when it is done.

The method to be adopted is this: the rosin is to be melted in an earthen vessel and a small quantity of beeswax added to it; the proportion of wax has to be determined by experiment. The use of the wax being to diminish the friability of the rosin without interfering with its hardness. Usually about one-fifth by weight of wax will be found a suitable quantity. The rosin and wax when fully melted and heated almost to boiling, is to be carefully poured over the wire by means of a spoon or ladle, turning the coil round and repeating the application until the mixture has com-

pletely permeated the strands and filled up all the interstices between the wires.

If this be done neatly, the paper covering will not be required; should, however, the outer surface of the coil be otherwise than smooth and even, the paper must be laid on as directed.

When the rosin mixture is employed as the insulating material, it will be found convenient to wind the wires on to the cylinder and insulate the same before the reel ends are fixed on.

55. The Secondary Coil.—This is also formed of copper wire, but the wire must be covered with *silk*, and of a size known as No. 38, averaging about 180 yards to the ounce; the quantity required will be about 6 ounces. In winding this wire on the reel, the most scrupulous care is needed, not only to avoid any break in the wire, but also any kink or bend in it. The diameter of this wire is 0067 in. The layers of the Secondary Wire should not be carried close up to the end of the Primary Coil, in order to avoid the possibility of the wire of one layer sinking down to the level of that below it. It must be borne in mind, that when a layer of wire is finished and insulated, it is next to impossible to take it off again; consequently every care must be taken to prevent any failure in winding it on. One layer of the Secondary Wire is to be wound on at one time and then most carefully coated with the shellac varnish

or with the rosin mixture (**54**). When this has been done, the layer of wire is further insulated by wrapping round it several thicknesses of gutta-percha tissue, or of thin white demy paper, previously soaked in the rosin mixture (**54**), and allowed to become hard.

Whichever material be used, it must be cut in strips a little wider than the length of the layer of wire it is to cover and then wound on tightly, but smoothly. The length of the strip should be such as to wrap three or four times round the coil, and it must be fastened with the varnish or rosin mixture. When the requisite quantity of wire is put on, eight or ten folds of the insulating paper or tissue must be wrapped round the coil before the ornamental covering of silk velvet is applied.

If the wires forming the coil have been put on before the reel ends have been fixed to the inner paper cylinder, the reel ends must now be put in their places, and when they are firmly set, the interspaces between the ends of the layers of wire and the inside of the reel ends should be carefully filled up with the rosin mixture (**54**) so that the insulation may be perfected.

The winding of the Secondary Wire should begin at the *opposite* end of the coil to that at which the winding of the Primary Coil commenced, and it must finish at the same end at which it began. The two ends of the wire should

be wound into two helixes, and these can be passed through holes in the reel ends, in order that they may be connected with the other part of the apparatus.

56. Testing the Secondary Wire.—Before the winding of the Secondary Wire is commenced it should be tested, which may be done in the following way:—Attach one end of the wire on the bobbin (as it comes from the coverers) to one electrode of a battery, and the other end of one of the binding screws of a galvanometer (**7**). The circuit is now to be completed by uniting the other electrode of the battery with the other binding screw of the galvanometer, and if there be no break in the wire a deflection of the needle will ensue. Should *no* deflection take place the wire must be unwound from the bobbin and carefully examined, and the break detected and soldered.

When the continuity of the wire has thus been ascertained or effected, the operation of winding it on to the reel can be commenced. Each layer of wire, as it is wound on and before it is insulated, should be tested by the galvanometer. For this operation, a different course to that just described should be adopted. The beginning of the Secondary Wire on the reel is to be connected with one of the binding screws of the galvanometer, and the end of the wire that still remains on the bobbin is to be attached to the other binding screw of the

same, *Fig.* 28. The two ends of the Primary Coil are to be connected with the battery, and if there be no fault in the Secondary Wire the needle of the galvanometer will be deflected; the layer can then be insulated (**55**), and the like course must be adopted with each layer.

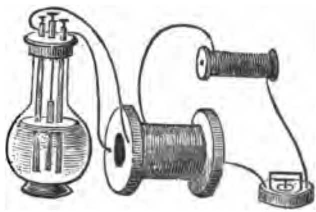

FIG. 28.

Should it be necessary to solder two ends of the Secondary Wire together, the silk coating must be removed from each end. The ends must then be carefully brightened, by rubbing them with fine glass paper. The ends of the two wires are to be put side by side in contact with each other, and a small piece of tinfoil wrapped round both wires, and moistened with a solution of muriate of zinc, and then moved over the flame of a very small spirit lamp, and in a few seconds the tinfoil will melt and unite the wires together. Should it be necessary to apply the wires again to the lamp, they must be first moistened with a fresh portion of muriate of zinc. The wires should overlap each other about half an inch, and when the soldering is complete, the silk covering is to be most carefully replaced.

57. The Iron Bundle.—This is simply a bundle of uncovered iron wires, about No. 18

gauge. The wires should be quite straight, and of exactly equal lengths, and about $\frac{1}{2}$ inch longer than the outside measurement of the coil. The centre of the coil is to be filled with these wires; and when this has been done, a short piece of larger wire, carrying on one of its ends a disc of iron about $\frac{1}{4}$ inch thick and $\frac{5}{8}$ inch diameter, should be pushed into the centre of the coil at each end, so as to secure the bundle in its place.

58. The Contact Breaker.—The form of Contact Breaker used for Intensity Coils is that known as the Vibrating Contact Breaker, a description of which has been previously given. In the form described (**51**), an electro-magnet was provided, so that such a contact breaker could be applied to any kind of apparatus whatever. But it is not desirable to use a separate electro-magnet for intensity coils, as a resistance is offered by it to the battery current, and therefore the iron bundle in the coil (**57**), which becomes an electro-magnet, is used instead.

This arrangement necessitates an alteration in the position of the spring and iron clapper, which,

Fig. 29.

as will be seen in the illustration, *Fig.* 29, is placed vertically. The spring is fixed to a brass block attached to the pedestal, the block having a vertical plate rising on one side. A screw passes through this vertical plate of the block, and comes

into contact with the spring a little way above its point of fixation to the block. The use of this screw is to increase or decrease the tension of the spring, and to regulate its distance from the end of the iron bundle. At the top end of the spring is an iron cylinder or clapper about ½ in. long, and of similar diameter, and the spring should be adjusted so that the face of this cylinder may, when the spring is at rest, be about ¼ in. from the end of the bundle. A strong brass pillar rises up also from the pedestal, and reaches a little above the centre of the coil. Through the top of this pillar a strong screw (called the platinum screw) passes, carrying on its end a piece of platinum, which comes into contact with the spring at, or a little below where the iron cylinder is attached to it. The spring at this part is armed with platinum, and it is here that the contact is made and broken. The platinum screw is provided with a running boss, so that when the screw is adjusted, the boss can be brought up tightly against the pillar, and thus prevent the screw from shifting. The surfaces of the platinum will require to be smoothed and scraped from time to time, in order to maintain complete contact. It will not be necessary to repeat here the reason why the spring vibrates; that has been fully described before (**51.**)

59. The Condenser.—This part of the apparatus is usually shut up in the cavity of the

pedestal forming the base, although it can, if preferred, be separate. The Condenser is the invention of M. Fiseau, of Paris, and its purport is to add to the energy of the current that traverses the primary wire, and consequently, to increase the force of the secondary discharge. The Condenser consists of a number of plates of tinfoil, separated by sheets of carefully-varnished or rosinized (**55**) paper, the alternate tinfoil plates being attached together, thus forming two separate insulated series. One series of the plates is connected with the pillar of the contact breaker that carries the platinum screw and the other series with the block that holds the vibrating spring. It will be seen from this, that these plates do not form part of the battery circuit, but are, as it were, lateral expansions of that circuit, on each side of the contact breaker. The insulating sheets between the tinfoil plates have by these means their electrical condition disturbed, and when the battery circuit is interrupted the plates return to their normal state, and, in so doing, increase the action of the current circulating in the primary wire.

The paper intended to be used for separating the plates of the Condenser, should be moderately thin, and not too heavily sized. The paper should be cut into pieces rather larger than is required, and then dipped into a solution of 1 oz. of shellac dissolved in 6 ozs. of methylated spirit, and hung

up to dry. The paper should remain suspended for some hours, and then be carefully examined sheet by sheet; and if the minutest pinhole be observed in any sheet, it must be rejected. A second coating of shellac varnish is now to be applied, and when thoroughly dry, the paper is ready for use. It must then be cut to the proper size, and preserved in a portfolio until required for use. Rosinized paper can be used instead of the varnished paper if preferred. In that case it should be prepared as before directed (**56, 57**). The ordinary tissue-paper does well for the purpose, but that known as white demy is perhaps the better kind.

The details of a Condenser for the Coil being described are these: Prepare 50 sheets of tinfoil, each 5 inches long and 5 inches wide, and also 60 pieces of insulating paper, each 7 × 5, and two thin boards of mahogany of rather smaller size, varnished on each side. One of the mahogany boards is to be laid down, and upon this five of the insulating papers are to be placed, and then one of the tinfoil plates, taking care to lay this latter down, so that one inch of its breadth projects over one side of the varnished paper. Another paper is to be laid on this, coinciding in position with the first paper, and upon this the second tinfoil plate is to be laid, but with the overhanging part coming out at the opposite side

to that of the former one. This is to be covered with an insulating paper, and then a third tinfoil plate is to be laid down, but the overhanging part of this plate is to be on the same side as the first plate. This is to be followed by the other plates in similar order, taking care that the ends of each alternate plate project at one side, and the ends of the intervening ones on the opposite side. When this has been done, five more papers are to be laid on, and, finally, the second mahogany board, and the whole is then to be tied up with gutta-percha string. All the projecting tinfoils at one side are to be pressed together, also those at the other side; the Condenser is then ready to be placed in the cavity of the pedestal.

60. The Pedestal or Base. — This should be made about 13 in. long, and 8 in. wide, and 2 in. deep. The bottom must be made moveable, and should be fixed by screws or buttons, and any kind of moulding can be placed round the pedestal, to suit the taste of the constructor. The coil is to be placed horizontally in the centre of the pedestal, and it will be necessary to make holes in the top, in order to fix the coil in its proper position. Other holes will be required in the top of the base, to allow the ends of the primary wires, together with the pillars and binding screws, to be passed through in order to attach them to their proper places underneath the same.

The Contact Breaker is to be fixed in its place at one end of the coil, and two binding screws are also required to be fitted to the same end of the pedestal. At the other end of the pedestal two pillars of ebonite are to be placed. These may be 6 inches high and about ½ inch diameter. If the ebonite be cut off about an inch longer than is required, the extra inch can be turned down to a pin about ¼ inch in diameter and a screw cut on its end. The holes in the pedestal are to be made sufficiently large to allow these pins to pass through, and the pillars can then be firmly fixed by putting a nut on the under side. On the top of each pillar should be a double binding screw, that is, a binding screw with two holes, and a separate screw to each. One of these holes is for the reception of one of the ends of the secondary wire of the coil, and the other hole in the same binding screw is to attach any apparatus that is to be employed in conjunction with the coil.

61. The Commutator.—This instrument is shown at *Fig.* 30, and its use is to change the direction in which the current flows through the primary circuit, and, of necessity, to change the direction of that in the secondary circuit also.

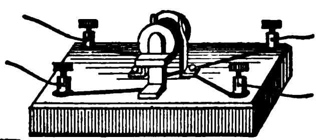

FIG. 30.

This, though an extremely useful addition to an Intensity Coil, cannot be regarded as one of its essential elements.

The Commutator consists of a cylinder of ivory or ebonite, and may be 1 inch long and 1 inch diameter. A metal axis should project from each end, and these two axes are not simply the ends of one piece of metal running through the cylinder; they are separate pieces, and must not be united together. Two plates of brass about $\frac{3}{4}$ in. wide are fixed to opposite sides of the cylinder, one of these plates being connected with one axis, and the other with the other axis. The cylinder is supported horizontally on two brass blocks or pillars, that are fixed to the base-board, and there are also two brass springs that rise up from the board, and press on the brass plates on the face of the cylinder. Four binding screws are also on the board; two are connected with the two springs, by wires passing underneath or over the base-board, and the other two binding screws with the blocks carrying the axes of the cylinder. One of the axes projects through the block in which it rests, and on this is fitted an ivory or ebonite plate, so as to enable the cylinder to be turned round when required. Two of the binding screws on the board are to be connected with the battery, and the other two binding screws with the apparatus to be operated with.

The current proceeds from the anode of the battery, through one of the binding screws of the Commutator, and from thence under or over the board to one of the springs, and proceeds up this to the plate on the ivory or ebonite cylinder it is in contact with. From thence it passes to the first axis, then through the block in which the axis rests, and out by the binding screw connected with that block to the apparatus, returning by the other spring plate and second axis to the battery. When the cylinder is turned half round, and without any other change in the arrangement, the current will pass through the *apparatus* in the opposite direction to what it did before. It will still proceed from the anode of the battery to the first spring, but that spring is now in contact with the plate that is connected with the second axis, and, therefore the current will proceed from this axis, and return to the battery by the first axis.

If the pedestal on which the coil is mounted be made sufficiently large, the Commutator can be fixed on to it, and then the separate stand and binding screws will not be required. The Commutator is not only capable of being used as a current reverser, but also as a current suspender; for if the cylinder be turned only one quarter of a revolution, the springs will rest upon the interspace between the two brass plates, and contact will be broken. This should always be done while

the arrangements for the secondary current are being made, in order to avoid receiving what might prove an unpleasant shock.

62. The Coil Connections.—A word of explanation may be here given as to the way of making the connections underneath the base-board, and it will be assumed that the Commutator is not on the base-board, but will be, if required to be used, a separate instrument. On turning the pedestal of the coil upside down, the under side will, when all the parts are connected together, present the appearance shown in *Fig.* 31. The letters A and B represent the ends of the binding screws to which the battery is attached; C is the end of the pillar of the contact breaker that carries the platinum screw; D is the end of the block that carries the spring forming the other part of the contact breaker; E and F are the beginning and end of the primary coil.

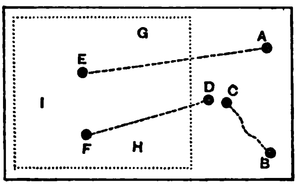

Fig. 31.

A loose board, I, should be fitted into the pedestal, and it should be fixed about half way up from the bottom. This is required to lay the Condenser on, and to afford convenient means for attaching it. The dotted lines will represent this loose board, and upon it, at G and H, two flat

plates of brass, about 1 inch square, are to be fixed, having a screwed pin in the centre of each. These plates are for connecting the Condenser with the contact breaker. The various screws spoken of should project through the top of the pedestal full $\frac{3}{8}$ of an inch, so as to enable nuts to be screwed over them. Three strips of sheet copper about $\frac{1}{2}$ inch wide are to be prepared, two of them having a hole at one end and a binding screw at the other, and the third one is to have a hole at each end. This latter one is to be long enough to connect B with C, as shown by the dotted line. This is done by dropping the strip over the projecting screws of B and C, then screwing a nut down tightly on to the copper, which will secure the strip, and make the requisite contact. The strips with binding screws are to be used to connect A with E, and D with F, the binding screws securing the wires E and F, and the holes in the copper strips enabling them to pass over the projecting screws D and A, where they are fixed by nuts, as in the former case. When the anode of the battery is attached to the binding screw which is seen at A, and the cathode to that at B, then the current will flow through the coil. The circuit will be seen to be complete in the direction of the dotted line A to E, through the primary coil, and out at F, then from F to D, and through the contact breaker to C, and from C to B.

The Condenser is to be laid down on the loose board I, with the projecting tinfoils resting on the brass plates G and H. A hole may be punched through each set of tin-foils, to admit the screw pin passing through them. A brass plate can then be laid on the top of the tin-foils, and by means of a nut on the screw pin they will be pressed closely together. When the Condenser has been fitted in its place, the nuts are to be loosened and the top brass plate taken off, and two copper strips with holes at each end fitted over the pins. These copper strips must be long enough to connect the pin G of the condenser with C of the contact breaker and the pin H with D, and when this is done, the nut may be screwed up tightly again. Should the Condenser not be thick enough to fill up the space between the loose board and the bottom, the latter must be padded, so that when it is put into its place it will press tightly on the Condenser, and prevent it from shifting.

63. Battery Power for the Coil.—The Coil is now complete, and it may be used with any battery equal in power to a Grove's battery of six cells. Less battery power can be employed if so desired, but then the full effects of the entire combination will not be obtained, and if the battery power be greatly in excess, the secondary wire may become heated, its insulations impaired, and *the coil utterly* ruined.

HOW AN INTENSITY COIL IS USED.

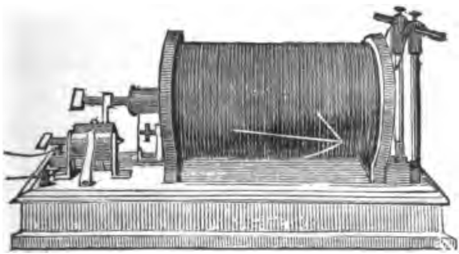

FIG. 32.

64. Electrodes of the Secondary Coil.—If two wires be affixed to the binding screws that represent the ends of the Secondary Coil, these wires are designated the Electrodes (**19**) of the Secondary Coil. And if these wires be attached to the Discharger mentioned below (**66**), then the ends of the rods of the Discharger are called the Electrodes.

65. Experiments with the Intensity Coil.—The experiments to be performed with the Intensity Coil are for the most part effects of the secondary current. They consist of luminous and calorific discharges, electro-chemical *phenomena*, inductive and physiological effects.

These experiments, for the sake of perspicuity, will be grouped together, and some instructions given for performing the same. The phrase, "Attach to the Coil," will be frequently used in describing these experiments; and that will be taken to signify that the apparatus in question is to be connected with the binding screws that represent the two ends of the Secondary Coil.

66. The Discharger.—In operating with an Intensity Coil, it will be found convenient for some experiments to employ a modification of the apparatus known as Henley's Discharger. This is represented in *Fig.* 33, and it consists of two glass

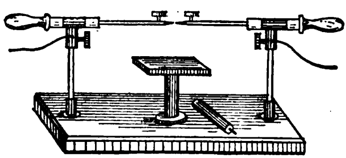

FIG. 33.

or ebonite pillars, rising up from a base-board and carrying two binding screws and horizontal tubes, through which two brass rods with insulated handles slide. The ends of these two rods are drilled up a short distance, and are provided with side screws passing into the holes so made. This arrangement is made in order to admit of the attachment of small wires for the purpose of performing various experiments. The binding screws

on the tops of the pillars are for connecting the Discharger with the Secondary Coil. A small ebonite table is fixed to the base-board, and upon this table can be placed anything that is to be operated on. This table fits into a socket, and can be removed when required.

67. Primary Spark.—When the battery is connected with the Coil, a small but intensely vivid spark is seen at the point of the platinum screw, where it comes into contact with the spring of the contact breaker **(51)**. This spark appears as though it were a brilliant star, and when the battery and coil are large, it has the aspect of a flame. This, although apparently continuous, is in reality intermittent, as no spark exists while the platinum screw is in contact with the spring.

68. Secondary Spark. — "Attach two wires to the Coil," and bring their ends near to each other. When the battery circuit is completed, a stream of sparks will pass between the wires, *Fig.* 34. These sparks are manifestations of the dynamic condition of the Secondary current **(14)**.

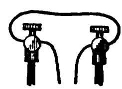

FIG. 34.

69. Static Spark.—Remove the wires from the binding screws of the Coil, and apply the knuckle or any other conductor to them. Sparks of a feeble brilliancy and of a comparatively loose *appearance*, will pass from one of them to the

knuckle, such sparks being the manifestation of the static condition (**15**) of the current.

70. Elongated Dynamic Spark.—Attach two moderately thin silk covered wires to the Coil, and direct the *end* of one towards the *side* of the other, and when they are sufficiently near to each other long brush-like dynamic sparks will pass between them. On examining the structure of the spark through a magnifier, it will be seen that the appearances of the two ends of the spark greatly differ. One end of the spark is the more brilliant, and of a red color, the other end being of a feebly luminous violet color, enveloping the entire end of the wire. These phenomena are more manifestly seen when the spark is passing through a vacuum (**116**).

71. Calorific Dynamic Spark.—Alter the position of the two wires or Electrodes (**64**), as they will in future be called, employed for the preceding experiment, and bring their *ends* opposite each other. Diminish the distance between the two wires, and the spark will become brighter and more intense, and assume a fiery red color. This is the condition of spark suitable for ignitions, and all calorific effects.

72. Intermittent Character of the Spark.—Arrange the electrodes (**71**) so as to obtain sparks of medium length. These sparks follow so rapidly upon each that the impression

of one spark does not fade from the retina of the eye before another spark passes. That these are sparks, and not a continuous flame, can be satisfactorily shown by the following experiment: Direct the eyes to the stream of sparks with somewhat vacant stare, and then, without moving the *head*, sharply turn the eyes, either upwards or downwards. This movement will cause the image of the sparks to fall upon successive portions of the retina, and a series of images, one below the other, will be seen, having the appearance of the rungs of a ladder.

73. Retaining Power of the Retina.—The impression made by a luminous object on the retina of the human eye lasts for about one-eighth of a second; therefore, when the *eye* is rapidly moved, the impression is retained on the retina *after* the light from the spark ceases to fall upon that particular spot, and thus the series of luminous images result. When a continuous light (such as that from a taper passing through a small hole in a card) is treated in the same way, an elongated image is seen, but not a succession of separate images.

74. Divergence of the Spark towards a Flame.—Arrange the electrodes so as to obtain the spark of average length, and, while the current is passing, bring the flame of a *small taper* near the stream of sparks. The char-

acter of the spark will be at once changed, its luminosity will be considerably diminished, and it will be attracted apparently by the flame, *Fig.* 35.

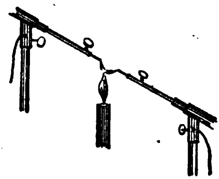

FIG. 35.

The heated atmosphere surrounding the flame, and the particles of carbon in the flame, form a better conducting medium than the ordinary atmosphere; and this is the probable explanation of the phenomenon.

75. Elongation of the Spark by a Flame.—Remove the taper from the *side* of the electrodes, *Fig.* 74, and place it with the flame fully below them. Under these circumstances, it will be found that the electrodes can be separated much farther apart than before. The spark becomes blue and loose, but three or four times longer than could otherwise be obtained. The rarefied condition of the air caused by the flame of the taper is the probable cause of this.

76. Action of the Flame of Bunsen's Burner.—Place a Bunsen's burner on a sheet of ebonite or gutta-percha, and attach one of the electrodes to some part of the same. Light the burner, and approach the other electrode to the part of the flame, and the spark will pass down it to the metal tube from whence the flame issues. If a little common salt be thrown into

the flame, its apparent conducting power is increased.

77. Change in Spark passing through a Flame.— Approximate the electrodes, *Fig.* 36, so as to obtain the calorific spark

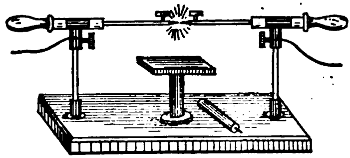

FIG. 36.

(**71**), and then bring the flame of a wax taper between them, so that the spark may pass just over the top of the wick. The spark will assume an egg-like form of intense whiteness.

Separate the electrodes a little, and elevate the taper. It will be seen to travel round the wick, forming an intensely blue stripe.

In performing these experiments, the ends of the electrodes will be blackened by a deposit of carbon from the flame of the taper. When the taper is taken away, and the electrodes approximated towards each other so as to produce the calorific spark, this coating will be rendered incandescent, and the ends of the electrodes will glow like vivid white stars.

78. Modification of the Spark by Surface.— Attach a metal ball, about $\frac{3}{4}$ inch

diameter, to one electrode, and approximate the end of the other electrode towards it, *Fig.* 37.

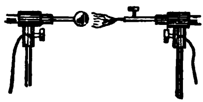

FIG. 37.

Under these circumstances the spark will be divided into a number of branches, radiating from the end of the electrode.

79. The Shield Experiment.—Remove the ball from the electrode, *Fig.* 37, and substitute a concave metal plate. A somewhat similar division of the spark will take place, but it will be accompanied by a loud report.

80. Apparent Bending of the Spark.—Arrange the electrodes so as to produce the elongated spark (**70**), and bring the edge of a gutta-percha or ebonite plate into contact with it, *Fig.* 38. The spark will be bent as though it were forced out of a straight line by the pressure of the plate against it.

FIG. 38.

81. Spark over Softened Gutta-Percha.—Approximate the two electrodes so as to produce more of a calorific spark (**71**), and then interpose a piece of thin gutta-percha. The spark will pass over the edge of the gutta-percha, which will become softened and partially transparent, and under these circumstances the zigzag form of the spark can be seen through the interposing sheet. In this softened state the gutta-percha

offers less resistance to the passage of the spark over it, and consequently the edge of the gutta-percha can be moved farther through the direct line of the spark.

82. Spark over Partial Conductor.—Moisten a plate of gutta-percha or ebonite, and then bring down the ends of the electrodes upon the wetted surface, *Fig.* 39. The spark under these circumstances will be greatly increased in length, and will assume a beautiful zigzag form, and be broken up into fragments or points of light.

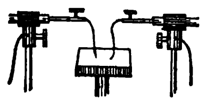

FIG. 39.

83. Fiery Scrolls. — Lay a plate of tin-foil on a piece of ebonite or gutta-percha, and bring one of the electrodes into contact with the margin of the plate. Arrange the other electrode so that it may stand over the centre of the tin-foil, leaving a distance between something more than that necessary for the calorific spark (**71**). The stream of sparks appears as though it was separated into a number of diverging rays, which, impinging on the plate, become formed into a snake-like shape.

84. Sheet of Fire. — Approximate the electrodes so as to obtain the calorific spark (**71**), and while the stream of electricity is passing blow upon it through a glass taper tube. The tube

may be attached to a small pair of bellows, or it may be blown through from the mouth.

The spark itself appears unaffected, and proceeds without any disturbance from the blast of air passing over it. But a long sheet of fiery-colored flame is driven out from the opposite side, apparently as though the air passing through the stream of sparks became ignited.

85. Spark over Finely-divided Metal. — Place some copper filings and steel filings in a mortar and rub them down very fine. Sift the combined dust lightly over a piece of ebonite or gutta-percha. Bring the two electrodes in contact with the metal filings, and the spark will dart in all directions, deflagrating in its passage some of the particles of metal, and acquiring thereby an artificial color.

86. Spark over Water.—Place a large drop of water on the surface of a glass or smooth ebonite plate, and bring the electrodes down towards the opposite margins of the water, *Fig.* 40. By this arrangement the spark will pass through a much larger space than it would if the water removed. The spark passes over or round the edge as it were of the water, and not through it.

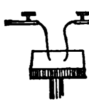

FIG. 40.

87. Spark obtained from Water.—Place one of the electrodes into an ordinary drink-

ing glass filled with water. On bringing the end of the other electrode towards the surface of the water, vivid sparks will pass between it and the water.

88. Action of Oil on the Color of the Spark.—Dip the ends of the electrodes in oil, and then approximate them so as to obtain the colorific spark (**71**). The color of the spark will be intensely green.

89. Spark not Extinguishable by Water.—To perform this experiment it is necessary to prepare two small glass tubes about two inches long, with one end of each bent at right angles. Through these tubes platinum wires are to be passed, so that they just come through the bent end of the tube. The glass at this end is to be carefully melted round the platinum, and when cold, any projecting wire is to be cut off, so that a surface of platinum equal only to the area of the section of the wire remains exposed. These tubes are to be fitted through a disc of cork, in such a way that the platinum ends may be opposite to and all but touching each other, *Fig.* 41.

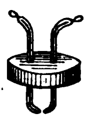

FIG. 41.

The disc of cork carrying the tubes is now to be laid on to the top of a glass vessel filled with distilled water, and the electrodes from the coil laid upon the platinum wires projecting from the upper ends of the two glass tubes. As soon as

the coil is in action, small vividly white sparks will pass through the water.

90. Influence of the Electric Current upon Oil.—Place upon the plate, *Fig.* 42, a globule of oil of larger or smaller dimension, according to the power of the coil employed. Bring down one of the electrodes near to the margin of the oil, and a slight commotion will be observed in it.

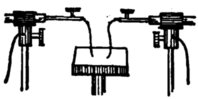

FIG. 42.

It appears as though that side of the oil were in a state of effervescence. Place the other electrode on the opposite side, and likewise near to the margin of the oil. The effervescence will be remarkably intensified and will manifest itself in apparent flashes, radiating from one electrode towards the other electrode, and pervading more than half the distance between them. These flashes are not electrical, but are only reflections of the light from the room, which falling upon the oil, shows the perturbations of its surface.

The margin of the oil opposite one of the electrodes will begin to thrust itself out, apparently attracted by it, and this will go on until the electrode is reached and enveloped. The side of the globule of oil towards the electrode now seems disintegrated, and appears to be driven towards the other electrode, a thin film only remaining, which *appears as* though it were dried by heat. This is

probably the explanation; the resistance offered by the oil to the passage of the current resolving some of the electricity into heat.

91. Apparent Impelling Power of the Current.—Place a small quantity of some light non-conducting powder on a plate of opal glass, and make a slight mound of it by gently tapping the under side of the glass. Let the base of the mound be more in diameter than the space through which the spark of the coil to be employed will pass. Place the ends of the two electrodes on the opposite edges of the powder, and barely in contact with it.

As soon as the coil is in action the particles of powder are to be in motion. One electrode seems as though it blew away the particles near to it, and a division begins to appear in the edges midway between the two electrodes. This rent increases until it reaches across the mass of powder, dividing it into two parts. The portion at one side continues to diminish by the particles being transferred across the channel between the two portions to the other side.

But the particles do not stop here; they are spread far and wide over the glass round the electrode, and arranged smoothly and regularly as a snow-drift. It is a noticeable thing that, although the particles seem thus blown away, yet a small quantity gathers round the electrode, completely

enveloping it some distance up from the end, while at the same time, although the particles are apparently blown toward the other electrode, yet the glass around its end is completely clear, as though it repelled all the particles immediately contiguous to it. Crystallized gallic acid is a very good powder to use for this purpose, as it consists of minute needle-shaped crystals, that are easily observed through a magnifier, and consequently the movement of the particles is clearly seen.

92. Dr. Wright's Cohesion Experiment. — For this experiment a clean plate of mica or glass is to be laid upon a metal plate, which should be, for the better display of the result, dead black. One electrode is to be attached to the plate, and the other placed vertically in the centre of the mica or glass, and in contact with it. A drop or two of liquid is to be placed on the glass, round the end of this electrode. As soon as the coil is in action a number of small points form at the margin of the drop of liquid, which push forward and become trunks from whence other tiny streams start. After continuing the action for some time the glass plate is covered with the most beautiful arborescent figures.

It is not of consequence which of the electrodes be in contact with the liquid, the only difference being a change of pattern. Different figures are produced by water acid, and saline solutions,

and the same solution acts differentially when placed upon mica or upon glass. The figures produced seem to be regulated by the cohesion between the fluid and the surface upon which it rests, and also by the cohesion of the particles of the fluid itself.

93. Disruptive Action of the Spark on Paper.—Lay a plate of tin-foil or other metal on a suitable support, and attach one of the electrodes to it. Place on this a piece of writing-paper, and bring the end of the other electrode near to it. As soon as the spark passes the paper is punctured, and by removing the electrode, and approaching it again to other parts of the paper, a series of holes can be made, and any required pattern can thus be pierced. If card be used instead of paper, an appreciable space of time must elapse before the electrode is removed in order thoroughly to perforate the card.

94. Peculiar Character of these Perforations.—It is worthy of note that these holes are cleanly pierced, without any burr on either side, the margins of the holes being blackened as though the paper were charred. In this respect they differ from the perforations made in paper or card by the charge of an ordinary Leyden jar. In this latter case there is a remarkable burr round the holes, as though they were punctured with an instrument that only thrust aside

the fibres of the paper, and did not remove the portion necessary to leave the hole.

95. Decomposition of Water.—This is shown by employing a cylindrical glass vessel, through the sides of which two platinum wires are passed, which should proceed some distance towards the centre of the cylinder, and then turn up at right angles, *Fig.* 43. The cylinder thus prepared should be partly filled with water well acidulated with sulphuric acid or vinegar, and it will then be ready for use. The two electrodes of the coil are to be attached to the ends of the platinum wires outside the cylinder, and as soon as the coil is in action small bubbles of gas will be seen to form on the wires in the water. These bubbles are oxygen gas and hydrogen gas, and are the components of the water.

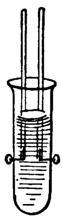

FIG. 43.

If a cork carrying two tubes closed at one end be fitted into the mouth of the cylinder, so that the open ends of the tubes come over the platinum wire, and the tubes be filled with the acidulated water by inverting the whole apparatus, the hydrogen gas will ascend into one tube and the oxygen gas into the other.

96. Decomposition of a Neutral Salt.—Dissolve starch in hot water, and dip into it strips of stout white blotting-paper, and hang them up to dry. When dry, moisten the surface

of one of the papers with a weak solution of iodide of potassium, and while wet place the paper upon a plate of glass or ebonite. One of the electrodes of the coil is to be attached to the margin of the paper, and the other electrode, which in this case must be armed with platinum, is to be brought in contact with its surface.

As soon as the coil is set in action, a purple spot is seen at the end of this electrode, resulting from the decomposition of the iodide of potassium, and the liberation of the iodine which unites with the starch in the paper, forming iodide of starch, the color of which is purple.

By employing an electrode with a smooth end, letters or devices may thus be produced, the electrode apparently writing or tracing a purple line (**44**).

97. Scintillation of Iron Wire.—Affix a short length of fine iron wire to each electrode, and bring the ends near together so as to obtain the calorific spark (**71**). The end of the wire attached to one electrode will become red-hot and ignite, while that at the other electrode will remain cool, *Fig.* 44. If the wires be surrounded by a glass tube about $\frac{3}{4}$ inch diameter, the cooling action of the atmosphere will be lessened and the deflagration *intensified.*

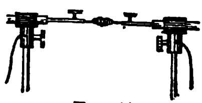

FIG. 44.

98. Deflagration of Leaf Metal.—Place a leaf of silver or gold, or Dutch metal, upon a sheet of paper, supported on ebonite or gutta-percha. Let one of the electrodes be in contact with one edge of the leaf, and approach the other electrode to the opposite edge. The metal deflagrates and disappears, coloring the spark and leaving an indelible stain upon the paper.

99. Ignition of Phosphorus.—Place a piece of phosphorus of the size of a small pea upon a glass plate, and allow the spark to pass through it. The phosphorus will be ignited, and burn with the usual dense white fumes. The phosphorus should be on a piece of glass or porcelain sufficiently large to prevent portions of the ignited phosphorus falling on to the table.

100. Inflammation of Ether.—Place a few drops of sulphuric ether upon a tuft of cotton wool, and by the aid of a pair of forceps hold the tuft of wool between the ends of the electrodes while the sparks are passing. The ether will be instantly ignited. The spark should be of a medium length, approaching to the character of the calorific spark (**71**).

101. Inflammation of Hydrogen Gas.—Arrange the electrodes so that sparks of medium length will pass between them. Direct a stream of the gas from an ordinary gas burner upon *the sparks*, and it will instantly burst into a flame.

102. Explosion of Gas and Common Air.—For this purpose a brass tube, shaped like a pistol barrel with a wooden stock, *Fig.* 45. is the most convenient apparatus. An ivory or ebonite plug must pass through one side of the barrel, carrying a wire that should come near to the opposite side of the barrel. The barrel is to be charged by holding its mouth downwards over an ordinary gas burner; the mouth is then to be closed with a cork. One electrode is to be attached to an eye in the barrel itself, and the other to the wire passing through the plug; the spark will then pass through the mixed gas and air, and ignite them and blow out the cork. In performing this experiment some care should be exercised, otherwise the barrel will be *entirely* filled with hydrogen gas. If this be the case it will not inflame.

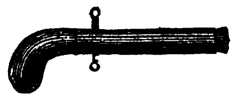

Fig. 45.

103. Ignition of Gun-Cotton.—Hold a tuft of gun-cotton by means of a pair of forceps in the stream of sparks, and it will instantly ignite and disappear with a feeble report.

104. Combustion of Lycopodium.—Scatter some lycopodium over a small tuft of cotton, and place some of the filaments in the stream of sparks; the lycopodium will be set on fire.

105. Re-lighting a Taper.—Ignite a taper and then blow it out, and when it has ceased

to smoke bring the wick between the ends of the electrodes, while the sparks are passing, and it will be re-lighted.

106. Explosion of Gunpowder.—For this experiment, the gunpowder should be finely pulverized and sprinkled on cotton wool, as was directed for the lycopodium (**104**). As soon as some of the filaments of the cotton carrying the gunpowder are brought into the stream of sparks the whole is ignited.

107. Galvanic Cartridge. — Twist together two short lengths of gutta-percha covered wire, leaving a portion of the wires at each end uncased. Bend the wires at one end a little bow form, so that the ends may stand opposed to each other and about $\frac{1}{8}$ inch apart. Cut off a short length of gutta-percha tube about $\frac{1}{2}$ inch in diameter and 1 inch long. Soften one end of the tube and place it over the bowed end of the twisted wires, and press down the sides of the tube, that it may come in contact with the gutta-percha coating of the wires and unite with the same. The cylinder thus formed, *Fig.* 46, is to be filled with fine gunpowder, and the end closed with a disc of gutta-percha. When this is neatly done, the powder will be enclosed in a water-tight chamber in contact with the ends of the wires. This may now be placed in a vessel of water and as soon as the

FIG. 46

outside ends of the twisted wires are attached to the electrodes, the cartridge will be exploded.

108. Statham's Fuse. — To form this fuse it is only necessary to take a length of copper wire, covered with vulcanized india-rubber, and fold it back upon itself and twist it together. The wire, near where it is bent, will require to have a portion of its covering cut away, so as to enable a part of the wire to be removed, leaving a break in it of about ¼ inch in length. This must be carefully done, so as not to damage the inside layer of the remaining covering. This portion of the covering should now be wrapped in a tuft of gun-cotton, and then protected by a suitable case. As soon as the two ends of the twisted wires are attached to a battery, the gun-cotton is exploded. The explanation is this: the contact of the vulcanized covering with the copper wire forms on the inside of the covering a coating of sulphide of copper. This is an imperfect conductor, and the current, intercepted in its flow by the break of the wire, proceeds over the coating of sulphide, which becomes ignited, and so inflames the gun-cotton.

109. Abel's Fuse. — This consists of a tube or chamber, having two wires passing into it. The ends of these wires must be farther apart than the distance capable of being traversed by the spark of the coil it is to be used with. The chamber is charged with a mixture of chlorate of

potassa, subphosphide of copper, and subsulphide of copper. These ingredients require to be mixed in proportions that will only partially conduct the current, in consequence of which, when the fuse is connected with the coil, heat is developed and the fuse ignited.

110. Charging a Leyden Jar.—Insulate a Leyden jar by placing it upon a plate of ebonite or other non-conducting substance, and attach one of the electrodes to the ball of the jar. The other electrode is to be placed some little *distance from* the outside coating of the jar, and as soon as the coil is in action the jar begins to charge and it can be discharged by an ordinary discharging rod.

This experiment is more interesting if, instead of employing a Leyden jar with continuous tin-foil coatings, one covered with diamond-shaped spots be used. The diamonds on the *outside* of the jar should be pierced through the centre, so as to allow the points of the diamonds on the inside of the jar to be readily seen.

111. Detonating Plane. — This piece of apparatus consists of a plate of glass about one foot square, having a coating of tin-foil on each side, with about one inch all round left uncoated. The plate should be supported on its edge on a sheet of ebonite or gutta-percha and one of the electrodes brought into contact with the tin-foil

coating of one of its sides. The other electrode is to be brought nigh to the opposite coating leaving about ¼ inch space between them, *Fig.* 47.

As soon as the coil is in action, sparks will be seen to pass between the electrode and the tin-foil, and in a few seconds a vivid flash will dart from one coating over the uncoated edge to the other coating, accompanied with a loud report. This report will be repeated at intervals as long as the coil is in action. The plate is, in fact, a coated Leyden surface, and the sparks over the edge are caused by the spontaneous discharge of the overcharged surfaces of the plane.

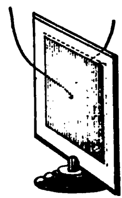

FIG. 47.

VACUUM EXPERIMENTS.

FIG. 48.

112. Spark in a Rarefied Medium. —The foregoing experiments are interesting and important in a scientific point of view, and many of them are extremely beautiful; but it is when

the electric discharge passes through transparent vessels partially exhausted that the incomparable splendor of these electrical phenomena are seen.

For such experiments the vessels must be of glass, and metallic wires must be inserted air-tight at the two ends, or at some suitable distance from each other, a portion of the wires remaining outside the glass vessel. The vessels may be large in diameter, or may be diminished to the size of tubes. They may be straight or bent and curved in any conceivable device (*Fig.* 48). They may be of ordinary glass, or of glass having certain metallic oxides in its composition. The vessels or tubes may be filled with the atmosphere in a highly rarefied state, or they may be filled with other gases, inorganic or organic, in a similar condition. If there be a perfect vacuum in the vessel, the spark will not pass at all, nor will it pass if the vessel be full of air of the ordinary density; a higly attenuated medium of some kind is essential.

The following pleasing experiment demonstrates the necessity of an atmosphere within any vessel that is to be made a pathway of the electric current.

For this purpose a small tube only is required, one about 3 inches long and ½ inch diameter will do very well. The metallic wires should pass into the middle of the tube, so that their ends may

almost touch each other. The tube so prepared is to be perfectly exhausted, and on connecting it with a coil, there will not be the faintest trace of a spark between the ends of the wires within the tube, although these may not be more than ·01 inch apart.

In attaching such a tube to a coil, it is usual to employ the discharger (**66**) for the purpose. In that case the rods of the discharger should be placed obliquely to each other across the base-board, that the ends may be approximated so as to obtain a calorific spark (**71**). The exhausted tube is now to be suspended to the rods of the discharger by means of fine uncoated wires, passing through the projecting wires on the ends of the tube. It will be seen that this arrangement establishes *two* modes of completing the circuit: one by the spark leaping the interval between the ends of the rods of the discharger, and the other by passing between the ends of the platinum wires within the tube; the space in one case being perhaps 3 inches, and in the other case ·01.; the larger space being moreover a space in air, and the smaller being a space in vacuo.

On attaching the rods of the discharger to the coil, the spark will pass in a stream between the ends of the rod, but not the least trace of spark can be seen inside the tube, thus proving

that the electric discharge will not take place in a vacuum.

113. Luminous Electric Globe.—Prepare a glass globe 5 or 6 inches in diameter, having a stopcock at one end and a cap at the other. Let a wire with a rounded end project from the inside of the cap at the top of the globe, and also from the end of the stopcock, likewise within the globe. When completed, the apparatus will be a glass vessel with a cap at each end, and with two rounded wires projecting opposite to each other, a short distance within the globe, *Fig.* 49.

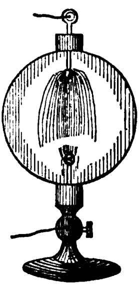

FIG. 49.

Let the globe be partially exhausted, and then connect the two electrodes of the coil with the two caps of the globe, and put the coil into action. Instead of a spark it may be $\frac{3}{4}$ inch or 1 inch long, such as could be obtained between the electrodes of the coil, a splendid stream of light is seen reaching across the inside of the globe from one wire to the other.

114. Stratification of the Spark.—Detach the globe from the coil, and exhaust it thoroughly, and then introduce a small portion of the vapor of alcohol, naphtha, or any similar *hydro-carbon.* Connect the globe again with the

coil, and it will be found that a great change has taken place in the character of the light. Instead of appearing now as a stream pouring from wire to wire, it will be divided into zones or belts, *Fig.* 50.

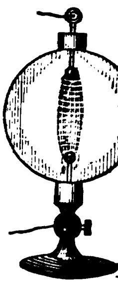
FIG. 50.

Frequently these zones appear as though they were slowly revolving on their own axes, having dark striæ over their edges. Such rotations are apparent only, for, from some experiments of M. Quel, there is reason to believe that such movement is only an optical illusion.

115. Attraction of the Spark by a Detached Conductor.—Arrange the luminous globe as in **113** or **114**, and while the stream of light is passing through the globe, hold the metal wire or other conductor to the outside of the globe, *Fig.* 51. The current will be diverted from its path and flow to the side of the globe where the conductor is.

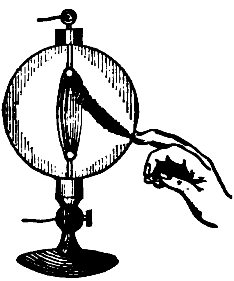
FIG. 51.

116. Different Appearances at the two Wires.—It has been before pointed out *(70) that* the two ends of the electric spark

passing between the electrodes of the coil greatly differed in appearance. This is seen in a much more palpable and beautiful manner in the exhausted vessels. The wires projecting into these vessels are, in fact, prolongations of the electrodes, and the appearance at each is most striking.

At the electrode which may be in effect designated as the anode, the manifestation is that of a vivid star, usually of a fiery red color, just at the end of the wire. At the cathode it is usually of a violet color, soft and diffused in appearance, and enveloping the sides of the wire as well as its end. Frequently it looks not much unlike a violet bulrush.

117. Change in the Color of the Spark.—Exhaust the globe, and then open the stopcock, so as to admit a very small portion of the atmospheric air, and connect it with the coil. The prevailing color of the stream of light now seen will be mauve. Again exhaust the globe, and admit a small portion of hydrogen gas. The color under these conditions will be mostly white. Once more exhaust the globe, and admit a like quantity of nitrogen, and the colors given will be rose, verging to deep orange. If the globe be again deprived of its atmosphere, and a small portion of carbonic acid be admitted, the color obtained will be pale green.

118. Fluorescence.—This term, fluorescence, is applied by Mr. Stokes to the property that some bodies have, of altering the refrangibility of certain rays of light that fall upon them. This causes rays of light that are produced by undulations too rapid to be appreciated by our visual organs to become visible; and also, by a like process, alters the colors of other rays.

119. Fluorescent Plate.—Examine a plate of glass, having oxide of uranium in its composition, by any ordinary light. It will appear of a feeble canary color. Place it near to an electric globe (**113**), or tubes (**123**), while the light is streaming thrcugh, and the uranium glass will be seen of a brilliant green color.

120. Fluorescent Writing.—Dissolve a portion of sulphate of quinine in water, and write with the solution on a piece of paper. When dry, and viewed in ordinary daylight, the writing is all but invisible; but when the paper is illuminated by the light from the electric globe (**113**), or tubes (**123**), the paper will appear as if written with beautiful blue ink.

121. Phosphorescence. — The word phophorescence is used to express the properties that some substances, organic and inorganic, have of emitting light when there is no combustion. It is also employed to signify the curious power that

some bodies have, when they have been exposed to light, of retaining the capability of exciting luminous undulations, and thus becoming visible in a dark room.

122. Phosphorescent Tube. — Fill a glass tube with dry sulphide of calcium or sulphide of strontium, and cork it up. View such a tube by the aid of light from the electric globe (**113**), or tubes (**123**), and no particular appearance will be manifested. Remove the tube to a dark room, and the powder will then be seen luminous with phosphorescent light (**132**).

123. Vacuum Tubes.— M. Geissler, of Bonn, first constructed the tubes designated "Vacuum Tubes," and they have since been largely manufactured in this country; being better known in England as "Gassiot" tubes. They consist of closed tubes with two platinum wires passing through their sides or ends, carefully melted in, and they are filled with the required vapor, and then hermetically closed. These tubes admit of all but endless variety of figures, and therefore the description of a few special forms will be sufficient.

When a vacuum tube is to be attached to a coil, one end of each electrode should be bent into the form of a hook, so as to unite more advantageously with the two projecting platinum wires in the tubes.

124. Gassiot's Cascade. — This is one of the most beautiful experiments that can be performed. The usual form of the apparatus is that of a cylinder of glass, slightly enlarged at each end bulb-form, *Fig.* 52. The upper bulb is divided from the rest of the cylinder by a glass partition, in the centre of which is a tube reaching down towards the lower bulb. This, like the upper, is separated by a glass partition, having one or more holes through it. On this lower partition is fixed a glass goblet, so arranged that the tube from the upper bulb comes down inside the goblet nearly to its bottom. The platinum wires for the electrodes are fixed one in the upper and the other in the lower bulb.

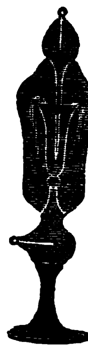

FIG. 52.

When such a vacuum tube as this is connected with a coil, the spark enters the upper globe and diffuses itself there. Then it passes down the centre tube, and emerges from its end on to the bottom of the goblet, rises from here up the inside of the goblet, pours over its edge, streams down the outside, through the hole in the bottom partition into the lower bulb, and finally escapes by the platinum inserted there. The goblets are usually made of uranium glass (**119**), so that they glow with a beautiful green light as though they were self-luminous.

125. Compound Vacuum Tubes.—This phrase is intended to signify a vacuum tnbe of any desired form or device enveloped in a glass chamber. This chamber has no connection with the interior of the vacuum tube, its purport being to form a hollow case or covering round the outside of the tube. The space between the two is filled with an aqueous solution of sulphate of quinine, or an alcoholic solution of stramonium, or a solution of æsculine. These solutions being fluorescent greatly add to the beauty of the device (**118**), communicating a colored margin (usually a bright blue) to the stream of light that passes through the tube.

126. Compound Volute Tube.—This tube is represented at *Fig.* 53, which may be taken as a type of the class of globe tubes. The general arrangements of these tubes may be thus described. The central portion is a large globe, containing within it a convoluted tube. This tube is sometimes, as in the illustration, a simple volute; other arrangements have more complicated figures, such as crowns, crosses, stars, etc. The central globe holds the tube, but is not connected with it; it forms, in fact, a chamber that is filled with one or other of the fluorescent solutions described

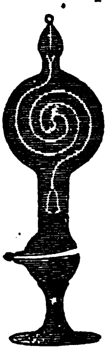

FIG. 53.

(**125**). The two ends of the convoluted tube enter into two smaller spheres, that contain the platinum wires. When such a tube as this is attached to the coil, the appearance is beautiful; the upper and lower globes are filled with a soft diffused light, of a rose or violet color. The convoluted portion, occupying the central globe, shines out with vivid brilliancy, of a uniform or varied colors, according as the glass of which it is composed is of one or mingled kinds. The fluorescent solution in the central globe gives a splendid fringe to the convolutions, and causes the whole to glow with colored light.

127. Compound Spiral Tube.—This tube is shown at *Fig.* 54, and is only a modification of the form of that previously described (**126**). There is the interior tube, of a zigzag or spiral form, having at each end a bulb, with the platinum wire, and surrounded with a containing cylinder for holding the fluorescent solution (**125**).

Fig. 54.

Fig. 55.

128. Double Branch Compound Tube.—The illustration given at *Fig.* 55 represents this class of tube. Each arm has the central convoluted

tube, one end of which is attached to the upper globe, and the other end to the U-shaped tube that joins them together. Each branch is surrounded with the enveloping chamber for the fluorescent solution (**125**), and the convoluted tubes are made of similar devices in each branch, and also with dissimilar devices. When the forms of the convoluted tubes in the two branches are alike, different varieties of glass are sometimes used, and sometimes different fluorescent solutions are employed in the two branches.

It will be obvious that the vacuum tubes can thus be varied almost indefinitely, every change in form or arrangement introducing a fresh variety of the most lovely combinations of colors that can well be imagined.

129. Horizontal Compound Spiral Tube.—Some devices show more advantageously when the tubes are horizontal, and these may be adverted to. At *Fig.* 56 one such tube is repre-

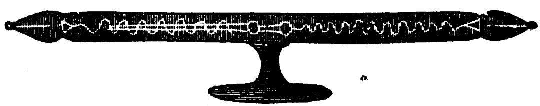

FIG. 56.

sented, with a spiral convoluted tube, surrounded by a single or double chamber for holding the *fluorescent* liquid (**125**).

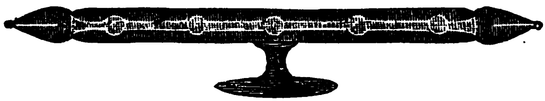

FIG. 57.

130. Horizontal Compound Bulb Tube.—This is shown at *Fig.* 57, and it consists of a series of short tubes, opening into a succession of bulbs, and surrounded by the enveloping chamber for the fluorescent fluid (**125**). This form of tube is varied by using different kinds of glass, as well as by the number and size of the bulbs.

131. Motto Tubes.—Specimens of these tubes are given at *Figs.* 58 and 59. The Convoluted Tube is bent into the shape of letters, forming in this case the motto, "God save the Queen." There is the enveloping chamber for the fluorescent fluid (**125**), and when such a tube is at-

FIG. 59.

tached to a coil the motto appears as though written in flaming letters.

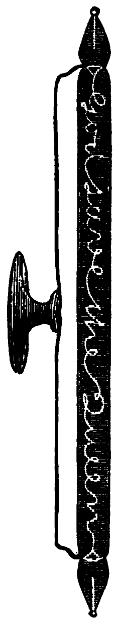

FIG. 58.

The second illustration, *Fig.* 59, is without the enveloping chamber, and the bulbs are blackened, so that the device only is seen.

132. Phosphorescent Vacuum Tube.—This is usually a cylindrical tube, with the platinum wire at each end, and containing dry sulphide of calcium. When attached to the coil, the inside of the tube is filled with a splendid stream of light, varying in color with the nature of the gas contained in it (**117**); the sulphide of calcium in the tube appearing like a reflecting surface, adding to the brilliancy of the light. On detaching the battery from the coil, or otherwise interrupting the passage of the electricity, the stream of light in the tube is instantly extinguished, but the sulphide of calcium continues to glow with phosphorescent light (**122**).

133. Seven Bulb Tube. — This is a beautiful kind of tube, and is usually made in the form of a triangle with three bulbs on one side, and one bulb on each of the other sides, the sixth and seventh bulbs carrying the platinum wires.

The appearance of this tube is very fine; the bulbs are filled with soft diffused light streaming round, and the connecting tubes look like intensely gleaming bands of fire.

134. Six Bulb Tube.—The usual form of this beautiful tube is that of six bulbs in a row with U-shaped glass tubes between them. By

this arrangement the electricity is caused to enter the first bulb by the platinum wire, and pass through the U-shaped tube to the upper part of the inside of the next bulb. The current then streams round the bulb, in order to find an exit at its lower side, when it enters the U-tube, and so on to the end of the series. The light in the bulbs is soft and diffused, while that in the U-tubes is vivid and brilliant, and usually manifest most strikingly the appearance of stratification (**114**).

135. Double Bell Tube.—This elegant tube, in its exterior form, consists of three bulbs united together by large cylindrical junction tubes. The first and last bulbs are separated from the other parts of tube by partitions of glass, from which partitions proceed small short tubes reaching nearly to the central bulb. These tubes terminate in contracted bell-shaped ends. When such a tube as this is attached to a coil, the first and last bulbs are beautifully illuminated with soft violet light, and at the same time the interior tubes glow with vivid light, which streams out of the mouth of the one bell, and, after proceeding in a diffused form through the central bulb, enters the open mouth of the opposite bell.

136. Combined Bulb and Spiral Tube.—This may be described as two bulbs *united* together by a convoluted tube. This tube,

for a short distance from each bulb, consists of a series of small bulbs with straight intervening tubes, the rest being twisted into a beautiful helix. An enveloping tube is usually provided for holding the fluorescent fluid (**125**); and the convoluted tube can be made of different qualities of glass, so as to give increased variety to the colors of the light.

137. Nine Bulb Tube.—This tube is made in the form of a circle about six or seven inches in diameter, and presents the appearance of a large central bulb surrounded by a ring having four large and four small bulbs arranged symmetrically upon it. This is one continuous channel, and when illuminated presents a ring of glowing bulbs hung upon a brilliant cord.

138. Pagoda Tube.—This tube consists of the nine bulb tube (**137**), supported upon a spiral cone. The effect of such a tube as this is really magnificent, showing one mass of glowing variegated light.

139. Triple Bar Tube.—This, like other of the complicated tubes, is difficult to describe. It consists of a central cylinder, with a series of small bulbs at each end. The ends of the cylinder are contracted and united to smaller tubes which are bent so as to form a tube on each side of the central cylinder. These side tubes have a series of bulbs arranged on them, and they each

eventually terminate in a large bulb. When illuminated, this complex tube has three lines of light parallel to each other, with the varying effects of fourteen bulbs of different sizes interspersed throughout its length. The effect of these combinations of figures is most beautiful and surprising.

140. Gassiot Star.—This is an apparatus for multiplying the effects of a single tube, and it accomplishes this by causing the tube to pass rapidly before the eye. The vacuum tube is attached to a wheel, *Fig.* 60, so that it may be rotated, the axis of the wheel being provided with proper arrangements for keeping the tube in contact with the coil. When the wheel is rapidly rotated the impression is retained on the retina of the eye, and, instead of one, a number of tubes, are seen, forming the radii of a star.

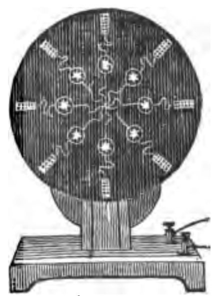

FIG. 60.

The wheel can be revolved by a handle and band, or it can be attached to a magnetic rotation machine, in which latter case it is self-acting.

141. Multiplying Planes.—This is an arrangement for increasing the effect of the vacuum tubes by multiplying their images by reflection.

The apparatus consists of two slips of silvered glass of a length equal to that of the longest tube that is to be used with it; the width of the glass plates should be about one-third that of their length. The plates are set up vertically with their faces towards each other, standing at an angle of 60 degrees one with the other. They are to be fixed in this position, and are to be provided with suitable connections, so that the tube may be held upright between them and attached to the coil. When the tube is illuminated, the image is reflected from both surfaces, and it is as though six tubes were being looked at instead of one only.

142. Injury to Vacuum Tubes.—It will be obvious from these descriptions of vacuum tubes that they are necessarily fragile articles, and require to be handled carefully, so as to guard them against breakage. But over and above such danger as this, they are liable to damage from the action of the electrical current itself.

If the power of the coil be greatly disproportioned to the length of the tube, it not unfrequently happens that the platinum wire becomes melted off inside the tube, and the tube spoiled.

Even though the tube and the coil be duly proportioned to each other, the end of the tube attached to the cathode will often become heated, and therefore the direction of the current ought *to be reversed*, or the tube should not be used for

any length of time without periods of cessation, so as to admit of the end becoming cool.

143. Union of Vacuum Tubes.—Tubes with comparatively short circuits can be united together, and fresh varieties can by these means be obtained. The only limit to such a union of tubes is the power of the coil. Each additional tube obviously lengthens the path through which the current has to travel.

144. Background for Vacuum Tubes.—Where it is practicable, it is best to have a black velvet screen behind the tubes, and if they can be also screened from top and side light, the beauty of the exhibition will be greatly enhanced.

145. Physiological Effects of the Intensity Coil.—These effects are obtainable from the primary as well as the secondary circuit, and they are most remarkable. When the force of the current is modified by reducing the battery power, or interposing a partially non-conducting medium between the conductors and the hands, or other part of the body to which the current is to be applied, the sensation experienced is that of a rapidly-repeated throbbing. By increasing the force of the current the gentle throbbing becomes more decided, and as the power is augmented assumes the character of a rigor. The muscles become contracted, and from a pleasant, almost soothing sensation, one of extreme pain

and agony is reached, which soon becomes intolerable.

146. Shock from Primary Circuit.—To obtain the primary shock, a separate or loop circuit must be established. This is affected by attaching a wire to the pillar carrying the platinum screw of the contact breaker (**58**), and fixing a similar wire to the block that carries the spring and clapper. To the end of these two wires metal cylinders or plates are to be fixed, and these are to be grasped in the two hands, or laid upon that part of the body which is to be acted upon.

It will be seen from this, that the primary circuit has now two channels, one through the contact breaker when the platinum screw is in contact with the spring, and at the same time a second channel by means of the wires just described and the person to be operated upon. But the conducting powers of these two greatly differ, and the consequence is, that so long as the platinum screw remains in contact with the spring, a perfect metallic circuit is thereby provided, and no current passes through what may be called the loop circuit. But as soon as the metallic circuit is interrupted by the severance of the spring from the platinum screw, the loop channel is brought into operation and a shock felt.

This shock is experienced every time the contact breaker vibrates, and the rapidity with which

this takes place causes the shocks to follow each other in such rapid succession that an almost continuous effect is experienced.

The reason why a shock is obtained when the battery current is passed through a coil has been before explained (**40**), and need not be repeated here.

147. Uni-direction Shock.—The effects just described are uni-direction shocks, the induced current flowing in the same direction as the battery current. Such a condition is of importance when the coil currents are to be employed for many physiological operations. The experiments previously detailed (**44, 96**), showed that many results are only obtainable at one of the two electrodes, and consequently any attempt to obtain physiological results analogous to the effects there described will fail unless the coil be so constructed as to give uni-direction currents.

148. Shock from Secondary Current.—To obtain these shocks from an intensity coil, it is only needed to fix the two wires with the metal cylinders to the electrodes of the Secondary Coil, and grasp the cylinders in the hands. The shock thus obtained from even the smallest intensity coil will be too strong to bear at all pleasantly, and therefore a modifying arrangement, such as the Water regulator, must be resorted to. Ordinary coils are so constructed as

to admit of such methods of regulation being parts of their formation. Intensity coils, however, cannot be so made, and therefore a separate instrument is required.

149. Water Regulator.—This is a glass cylinder about half-inch internal diameter, and from 5 to 12 inches long, fixed into a metal cap upon a foot. The upper end of the tube is also closed with a metal cap, through which a metal rod slides, *Fig.* 61. The length of the sliding rod should be something more than that of the tube, so that when occasion requires, the rod may be brought into contact with the inside of the cap forming the base of the tube. The glass tube is to be filled with ordinary soft water, and then it is ready for use. The binding screw in connection with the bottom cap is to be attached to one of the electrodes of the secondary coil, and the wire from one of the metal cylinders is to be attached to the sliding rod by means of the binding screw on the top cap.

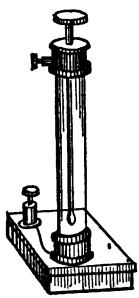

Fig. 61.

It will be perceived from this description that the course of the current from one of the electrodes is through the sliding rod and the bottom cap, and therefore, when the rod is drawn up so as not to be in contact with the bottom cap, the cur-

rent has to pass through the water that intervenes between the end of the rod and the cap. The water being an imperfect conductor of the current, a certain amount of resistance is offered to its passage, and the force of the shock thereby lessened. By drawing the rod farther away from the cap a greater depth of water has to be traversed, and thus the shock can be modified to any required degree.

150. Alternate Character of the Secondary Shock.—It has been previously shown (**36, 37**) that the induced currents on completing and breaking the battery circuit flow in opposite directions, and consequently the shock obtained from the secondary coil is not a uni-direction shock (**148**), but a bi-direction. The current consequent upon *completing* the battery circuit is less in force than that set up when the battery circuit is *interrupted* (**37**).

151. Electric Light from Carbon Points.—This light is the result of an incandescent condition of two pointed pieces of carbon when they are made the terminals of the electrodes of a compound galvanic battery.

Sir Humphrey Davy appears to have been the first to obtain this light, and his researches form the basis of all subsequent experiments. Davy found that when the electrodes of a powerful battery were armed with carbon points and brought

into contact, the points became incandescent, and emitted an intensely powerful light.

If the points be made of the carbon that is found deposited in the necks of the iron retorts employed in the manufacture of coal-gas, very little combustion of the carbon takes place, there being only a slow transference of particles from the carbon connected with the anode of the battery to that which is united with the cathode.

The different parts of the apparatus may be thus described: the battery, the carbon-holder or lamp, and the reflector.

152. Battery for the Electric Light.—The Grove's (**29**), or the Bunsen's (**30**) battery is the most suitable for producing the electric light. Any number of cells from six upwards can be used, and they should be arranged as an intensity (**22**) battery. If, however, a very considerable number of cells are to be employed, it will be more advantageous to unite them in couples or triples quantitatively, and then unite these multiples intensitively.

153. The Electric Lamp.—This, in its simplest form, consists of two metal sockets for holding the carbon points, placed either vertically or horizontally with their ends opposed to each other. Binding screws have to be provided for attaching these sockets to the battery, and some convenient arrangement is also neces-

sary for approximating the carbon points as they require it.

154. The Reflector.—This is only required when the light is to be projected in any one given direction. It is necessary then to employ a reflector of the parabolic form. This is to be so placed that the ignited carbons may be in the principal focus of the parabola, and then the light from the sides and back of the carbons will impinge on the surface of the reflector, and the whole will be projected forward in parallel or slightly diverging lines.

155. Mode of Igniting the Electric Lamp.—The battery that is to be used is to be excited, as before described (**29**, **30**), and then attached to the binding screws of the lamp. The carbon points are to be brought into contact, and as soon as they touch one another, the battery circuit is completed, and the points become incandescent. If the battery be capable of evolving a current of sufficient power, the carbon points can be removed from each other a given distance, the interspace will then be filled with an arc of vivid light. Should the points be removed too far from each other, the current will be interrupted, and the light will instantly cease. In such a case the points of the carbons must again be brought into contact, in order to re-establish the current. If the carbon points are placed *vertically*, the anode

of the battery is to be connected with the *upper* carbon, and the cathode with the *lower* carbon.

156. Dubosq's Electric Lamp.—This extremely ingenious apparatus is the invention of M. Dubosq, of Paris. It may be described as a hollow cylinder, supported on a pillar and foot. A central stem rises from the top of the cylinder, and another longer stem rises also out of the top of the cylinder, but nearer to its margin, and carries a bar at right angles to itself. The pillar supporting the cylinder is an electro-magnet (**11**), the coils of wire of which form a portion of the battery circuit. The cylinder contains a horizontal axis carrying two toothed wheels differing in diameter. One of these (the larger of the two) works in a long rack that forms the end of the long stem, before described as rising out of the top of the cylinder, and the other wheel (the smaller of the two) works in a similar rack that forms the end of the stem that rises out of the *centre* of the cylinder, the wheels being so placed that the two racks work on their opposite edges.

A carbon point is put into the *central* stem, and another fixed to the under side of the right-angle bar that projects from the top of the *side* stem, the carbons being so arranged that their points come exactly opposite to each other. When this has been done, the SIDE stem will descend by its own weight, and approximate its carbon to-

wards that fixed to the CENTRAL stem. But, in so doing, it turns round the wheels just described, and by this means the carbon in the central stem is *raised* up to meet the descending carbon. In consequence of the dissimilarity in the diameter of these wheels, the central stem does not proceed upwards so fast as the side stem descends, and this difference is arranged so as to compensate for the inequality of rate at which the two carbons waste away.

When the points of the carbons come into contact all further movement is prevented, one point resting on the other. The lamp is now ready to be attached to the battery, which is effected by fixing the electrodes of the battery to two binding screws attached to the lamp. The current passes up the side stem through the two carbons and the central stem, to the wire coiled round the iron bar forming the pillar (converting this into an electro-magnet), and so to the cathode of the battery, and the carbon points will become intensely incandescent. The horizontal axis, carrying the two toothed wheels, is now to be turned by means of a milled head on the outside of the cylinder, which will separate the carbon points, and this is to be continued until the maximum light is obtained. Associated with the two toothed wheels on the horizontal axis, before described, is a small train of wheels terminating in an escape-

ment, the pallet of which is attached to a vertical bar, rising up from the bottom of the cylinder. The end of this pallet bar (as it may be termed) is connected with one end of a lever, the other end of which holds an iron plate, coming immediately over the end of the iron bar of the electro-magnet.

The use of this arrangement is to compensate for the wasting away of the carbon points after the battery has been connected and the proper distance between them adjusted. This result is thus accomplished; the iron bar is formed into a magnet as soon as the battery current circulates round it, and this draws the end of the lever, carrying the iron plate downwards, and thus moves by its opposite end the pallet bar, which is turned round so that the pallet comes in between the teeth of the escapement wheel, and all further movement of the points is arrested. But when the points waste away the distance between them becomes greater, and the battery current is thereby impeded. This lessens the attractive force of the electro-magnet, and it ceases to hold down the iron at the end of the lever. This movement of the lever acts also on the pallet bar, and carries the pallet out of the escapement wheel, the train of wheels is released, and the carbons gradually approach each other. When these have come near enough to allow the battery current to pass *in full* force the power of the electro-magnet is

restored, the end of the lever is again drawn down, and this moves the pallet into the escapement wheel, and all further movement is stopped; this being repeated again and again as the points wear away.

157. Complete Electric Light Apparatus. — Under this designation a compact apparatus has been recently introduced. It has attracted some attention, as it illustrates well the mode of obtaining light from carbon points, and is both inexpensive and effective.

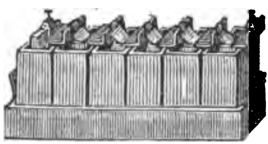

Fig. 62.

It comprises a six-cell Grove's Battery of the ordinary size and form, as will be seen in *Fig.* 62, and is provided with proper means for attaching the same to the lamp.

The lamp *Fig.* 63, may be described as consisting of a wooden foot, with a central rod carrying a horizontal arm, through the end of which slides a tube, which is the upper carbon-holder. A similar carbon-holder is attached to the wooden foot, and rises up vertically exactly opposite to the upper holder. Each

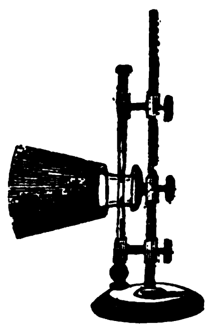

Fig. 63.

holder has a binding screw, and to these the battery is to be attached. The anode of the battery being fixed to the upper carbon-holder and the cathode to the lower.

The upper carbon-holder moves sufficiently easily through the end of the bar that holds it to descend by its own weight, and the points are thus brought into contact. No contrivance is necessary for separating the points, for the power of the battery supplied with this lamp is not sufficient to admit of any appreciable space between the carbon points. The maximum effect is produced when the carbons are carefully pointed and the ends just in contact.

The reflector is a substitute for a parabolic mirror. It is formed of two parts, united together by bands, leaving an interspace sufficiently wide to admit the carbon-holders between them. The end of the reflector is a small deep concave silvered mirror, and this has attached to it a socket that passes over the central stem of the lamp, and is fixed by a screw in the required position. The front part of the reflector is a truncated cone of planished tin, japanned outside, the smaller end being equal in diameter to that of the small concave mirror. The two are united together by bands, and form an approximate parabola of about 1½ inch principal focus. The front of the reflector is arranged *so as to* admit of colored glasses being applied, in

order, when desired, to intercept some of the component rays and emit only colored light.

Although much has been expected from electricity as an illuminating agent, yet hitherto the investigations that have been carried on have been comparatively barren of results. A cheap source of electricity will probably have to be discovered before electric illumination will be able to compete with the modes of artificial lighting now in use.

THE END.